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ALTERNATIVES TO THE MANAGEMENT OF HAZARDOUS WASTES AT NATIONAL DISPOSAL SITES. VOLUME II. APPENDICES

Arthur D. Little, Incorporated

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This report defines and evaluates on technical, economic, risk, and legal grounds the various alternatives for managing hazardous wastes. The basic alternative approaches that were considered included: (1) on-site processing; (2) off-site processing; and, (3) on-site pre-treatment with off-site treatment and disposal. The major emphasis of the study, therefore, was devoted to assessing differences among these alternative approaches in: the economics associated with waste treatment; the immediate risk to human safety, as well as the eventual hazard to the environment and, the legal and institutional issues that would have an impact on a national treatment system. The major and significant conclusion of this report is that on economic grounds alone, off-site treatment facilities will be preferred by a majority of producers of industrial hazardous wastes, with the possible exception of those who handle explosives and dilute aqueous wastes. Although the shape and form of the processing system may very, because of individual differences, this conclusion will be true for all regions of the United States.

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ALTERNATIVES TO THE MANAGEMENT OF HAZARDOUS WASTES AT NATIONAL DISPOSAL SITES

VOLUME II – APPENDICES

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APPENDIX A

LISTS OF WASTES

TABLE A.1

Hazardous Wastes Selected by TRW for National Disposal Sites (through TRW 8th Monthly Report)

Inorganics

Compound	TRW Code No.
Cyanides	
Calcium Cyanide	91
Cadmium Cyanide	84
Copper Cyanide	120
Lead Cyanide	239
Mercuric Cyanide	254
Nickel Cyanide	295
Potassium Cyanide	344
Silver Cyanide	370
Sodium Cyanide	387
Zinc Cyanide	457
Arsenites and Arsenates	
Calcium Arsenite	88
Copper Arsenate	119
Copper Acetoarsenate	490
Lead Arsenate	235
Lead Arsenite	236
Manganese Arsenate	500
Potassium Arsenite	341
Sodium Arsenate	377
Sodium Arsenite	376
Zinc Arsenate	453
Zinc Arsenite	454
Chromates	
Ammonium Chromate	21
Ammonium Dichromate	22
Chromic Acid	114
Potassium Chromate	343
Potassium Dichromate	345
Sodium Chromate	386
Sodium Dichromate	379
Arsenic Compounds	
Arsenic Trichloride	47, 50
Arsenic Trioxide	87

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TABLE A.1 (Cont.)

Inorganics (cont.)

	TRW Code No.
Antimony Compounds	
Antimony Pentafluoride	36
Antimony Trifluoride	43
Cadmium and Compounds	
Cadmium Oxide	81, 85
Cadmium Metal	82
Cadmium Chloride	83
Cadmium Phosphate	86
Cadmium Nitrate	479
Cadmium Potassium Cyanide	489
Cadmium Sulfate	481
Mercury and Compounds	
Mercury	257
Mercuric Chloride	253
Mercuric Nitrate	255
Mercuric Sulfate	256
Mercuric Ammonium Chloride	503
Chromium (III) Salts (Sludges only)	
Fluoride	485
Sulfate	486
Cyanide	487
Other	
Nickel Carbonyl	293
Carbonyl Chloride	101
Perchloryl Fluoride	326
Chlorine Trifluoride	106
Bromime Pentafluoride	66
Fluorine	200
Chlorine	105
Boron Hydrides	61
Pentaborane	505
Hydrogen Sulfide	221

TABLE A.1 (Cont.)

Organics	TRW Code No.
Pesticides	
Aldrin	13
Benzene Hexachloride	55
2,4-D (2,4-Dichlorophenoxyacetic Acid)	135
DDD	136
DDT	137
Dieldrin	147
Dinitro Cresols	162
Endrin	170
Ethylene Bromide	182
Methyl Bromide (Bromomethane)	267
Methyl Chloride (Chloromethane)	268
Methyl Parathion	274
Parathion	321
Chlordane	484
Demeton	491
Guthion	495
Heptachor	
Aliphatic Halogenated Hydrocarbons	
Carbon Tetrachloride	100
Chloral Hydrate	104
Chloroform	109
Dichlorofluoromethane	142
Dichloroethyl Ether	143
1,2-Dichloropropane	145.363
1,3-Dichloropropene	146
Dichlorotetrafluoroethane	147
Epichlorin	171
Ethyl Chloride	180
Ethylene Dichloride	185
Methyl Chloroformate	269
Perchlorethylene	325
Polyvinyl Chloride	340
Tetrachloroethane	424
Trichloroethane	437
Trichloroethylene	438
Trichlorofluoromethane	439
Vinyl Chloride	450
Aromatic Halogenated Hydrocarbons	
Chloracetophenone	107
Chlorbenzene (Chlorbenzol)	108
o-Dichlorobenzene	140,278
ρ-Dichlorobenzene	141
Trichlorobenzene	436
Hexachlorophene	497

TABLE A.1(Cont.)

	TRW Code No.
Organics (Cont.)	
Other	
Chloroacetophenone	107
Nerve Gas (non-persistent) (DOD)	287
Nerve Gas (persistent) (DOD)	288
Nitrogen Mustard (DOD)	306
Nitroglycerin (DOD)	307
Acrolein	8
Dimethyl Sulfate	160
Dinitro Cresols	162
Dinitrotoluene	165
Tear Gas (CN and CS)	422,423
Tetraethyl Lead	425
Tetramethyl Lead	427
Organo Mercury Compounds	258
Explosives	
Picric Acid	338
Copper Acetylide	517
Silver Acetylide	537
Cyanuric Triazid	519
Primers and Detonators	520
Diazodinitrophenol (DDNP)	521
Dipentaerythritol Hexanitrate (DPEHN)	522
Gelatinized Nitrocellulose (PNC)	523
Glycol Dinitrate-Nitroglycerin	525
Lead Azide	529
Lead Styphnate	531
Mannitol Hexanitrate	532
Mercury Fulminate	533
Potassium Dinitrobenzfuroxan (KDNBF)	536
Silver Azide	538
Tetrazene	542
Radioactive	
Cesium-134	
Cesium-137	
(Barium)-137m	
Plutonium-238	
-239	
-240	
-241	
Americium-241	
-243	

TABLE A.1 (Cont.)

Radioactive (Cont.)

- Curium-242
- Ruthenium-106
    - (Rhodium)-106
- Cerium-144
    - (Praseodynium)-144
- Promethium-147
- Strontium-90
    - (Yttrium)-90
- Zirconium-95
- Niobium-95
- Carbon-14
- Cobalt-60
- Iridium-192
- Radium-226
- Iodine-129
- Iodine-131
- Krypton-85
- Zenon-133

TABLE A-2

Categorization of Wastes for Detailed Study

ADL Category			Chemical Compound	TRW*
General	Sub-Class	ADL No.		No.
Antimony Compounds		1	Pentafluoride	36
			Trifluoride	43
Arsenic Compounds	Arsenates	2	Calcium	87
			Copper	119
			Lead	235
			Manganese	500
			Sodium	377
			Zinc	453
	Arsenites	3	Calcium	88
			Copper Aceto	490
			Lead	236
			Potassium	341
			Sodium	376
			Zinc	454
	Other	4	Trichloride	47,50
			Trioxide	87
Cadmium and Compounds	Soluble	5	Chloride	83
			Nitrate	479
			Sulfate	481
	Insoluble	6	Oxide	81,85
			Metal	82
			Phosphate	86

TABLE A-2 (Continued)

Category			Chemical Compound	
General	Sub-Class	ADL No.	Name	TRW No.
Cyanides	Soluble	7	Sodium	387
			Potassium	344
	Insoluble	8	Copper	120
			Zinc	457
			Cadmium	84
			Potassium Cyanide	489
			Lead	239
			Mercuric	254
			Silver	370
			Calcium	91
			Nickel	295
Chromium Compounds	Soluble Chromates/ Dichromates	9	Ammonium	21,22
			Potassium	343,345
			Sodium	386,379
			Chromic Acid	114
	Chromium III Sludges	10	Fluoride	114
			Sulfate	486
			Cyanide	487
Mercury and Compounds	Metal	11	Mercury	257
	Organo Mercury	12	Organo Mercury	258
	Inorganic Compounds	13	Chloride	253
			Nitrate	255
			Sulfate	256
			Ammonium Chloride	503

TABLE A-2 (continued)

Category			Chemical Compound	
General	Sub-Class	ADL No.	Name	TRW No.
Other Inorganics	Carbonyl	14	Nickel	293
	Interhalogens	15	Bromine Pentafluoride	66
			Perchloryl Fluoride	326
			Chlorine Trifluoride	106
			Fluorine	200
			Chlorine	105
			Carbonyl Chloride	101
	Miscellaneous	16	Hydrogen Sulfide	221
			Diborane	61
			Penta Borane	505
Pesticides	Chloro Organics	17	Aldrin	13
			Benzene Hexachloride	55
			2,4-D	135
			DDD	136
			DDT	137
			Dieldrin	147
			Endrin	170
			Heptachlor	496
			Chlordane	484
	Halogen Containing Gases	18	Ethylene Bromide	182
			Methyl Bromide	267
			Methyl Chloride	268
	Organic Phosphates	19	Demeton	491
			Guthion	495
			Methyl Parathion	274
			Parathion	321

TABLE A-2 (Continued)

Category			Chemical Compound	
General	Sub-Class	ADL No.	Name	TRW No.
Pesticides	Nitro Compounds	20	Dinitro Cresol	162
Miscellaneous Organics	Aliphatic Halogen Containing Compounds	21	Carbon Tetrachloride	100
			Chloroform	109
			Dichlorofluoromethane	142
			Dichloroethyl Ether	143
			1,2-Dichloropropane	145,363
			1,3-Dichloropropene	146
			Dichlorotetrafluoroethane	147
			Ethyl Chloride	180
			Ethylene Dichloride	185
			Methyl Chloroformate	269
			Perchloroethylene	325
			Tetrachloroethane	424
			Trichloroethane	437
			Trichloroethylene	438
			Trichlorofluoromethane	439
			Vinyl Chloride	450
	Aromatic Chlorine Containing Compounds	22	Chloroacetophenone	107
			Chlorobenzene	108
			o-Dichlorobenzene	140,278
			p-Dichlorobenzene	141
			Trichlorobenzene	436
			Hexachlorophene	497
	Organo Lead	23	Tetramethyl Lead	425
			Tetraethyl Lead	427

TABLE A-2 (Continued)

Category			Chemical Compound	
General	Sub-Class	ADL No.	Name	TRW No.
Miscellaneous Organics	Other Organics	24	Acrolein	8
			Dimethyl Sulfate	160
			Dinitro Toluene	165
DOD Type Compounds		25	Nerve Gas	278,288
			Nitrogen Mustard	306
			Tear Gas	422
			CS	423
Explosives	Liquid Nitrate Esters	26	Nitroglycerin	307
			Glycol Dinitrate	525
	Solid Nitrate Esters	27	Dipentaerythritolhexanitrate	522
			Gelantinized Nitrocellulose	523
			Mannitol Hexanitrate	532
	Aromatic Nitro Compounds	28	Picric Acid	338
			Furoxan (KDNBF)	
	Initiating Agents	29	Lead Styphnate	531
			Tetrazene	542
			Diazodinitrophenol (DDNP)	521
	Heavy Metal Explosive Salts and Oxides	30	Copper Acetylide	517
			Silver Acetylide	537
			Silver Azide	538
			Mercury Fulminate	533
			Lead Azide	529
			Cyanuric Triazide	519

TABLE A-2 (Continued)

Category			Chemical Compound	
General	Sub-Class	ADL No.	Name	TRW No.
Explosives	Primers and Detonators	31	Contain variety of compounds as above	520
Radioactive	Wastes from Nuclear Fueled Reactors	32	Cesium-134, Cesium-137 (Barium-137m) Plutonium-23,239,240,241 Americium-241,243 Curium-242,244 Ruthenium-106 (Rhodium-106) Cerium-144 (Preseodymium-144) (Promethium-147) Strontium-90 Zirconium-95, Niobium-95	
	Other (limited quantity	33	Cobalt-60 Iridium-192 Krypton-85 Zenon-133	
	Other (widely used)	34	Carbon-14 Iodine-129,131 Radium	

*TRW No. refers to list

APPENDIX B1

DESCRIPTION OF WASTE TYPES

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BACKGROUND

To apply the decision map model for selecting between alternatives on an economic basis, it was necessary to develop a general understanding of the types of industries that generate hazardous waste streams as well as detailed information on specific waste streams which currently exist and thus are potential candidates for Central Processing Facilities. This section describes the results of a general overview as it applies to:

- Organic wastes suitable for incineration;
    - Chloric organic solvents
    - Pesticides
    - Paints
- Waste streams containing heavy metals and/or cyanides;
    - Electroplating
    - Tanning
    - Battery manufacturer
    - Cooling tower blowdown
    - Smelting and Refining
    - Chlor alkali plants

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ORGANIC WASTES SUITABLE FOR INCINERATION

Within the list of Category I wastes (see Appendix A), the categories which could utilize incineration as the treatment process are pesticides, the chloro organics, some miscellaneous organic compounds, and wastes from the paint industry which contain heavy metal pigments.

Chloro Organic Solvents

The potential sources of industrial wastes for these compounds were explored in two ways. First, the producers were examined in terms of plant capacity and the process employed. Second, the major users (by volume) were studied to determine whether unreasonably large volumes might be encountered at many individual use points. In both of these situations, it is important to recognize that an effort was only made to determine whether the industry segment had many large sources. If most individual plants in the industry generated less than 10 million gallons/year, this was taken as support of the conclusion that the chloro organic wastes would be treated off-site.

With a few possible exceptions, such as those producing vinyl chloride and ethylene dichloride, most of the plants that produce chloro organic solvents will have waste streams of well under 10 million gallons per year. Similarly, almost all users of these solvents have waste volumes much lower than 10 million gallons per year. Thus, most plants producing or utilizing these solvents will probably have need on an economic basis, for a central processing facility to treat their wastes.

A summary of the production volumes for the chloro organics of interest to this program is given in Table B.1.1. Details on various compounds are given below.

C_1 Compounds. The compounds in this category include: methyl chloride, methyl bromide, methylene chloride, chloroform, carbon tetrachloride, trichlorofluoromethane, and dichlorodifluoromethane. A few isolated plants may have sufficient waste volume to perform their own treatment.

Methyl Chloride. Roughly a dozen producing plants make methyl chloride. All but two are located in the Middle Atlantic, Southeastern and Gulf Coast states; the remaining two are in the Midwest and the Far West. Two basic processes are used to make methyl chloride. The first is based on the reaction of methanol and hydrochloric acid and leads to higher direct yields of methyl chloride. Plant capacities range from 0.5 million to 13 million gallons per year. The second method utilizes the chlorination of methane with plant capacities ranging from 1 million to 13 million gallons per year. Total production for 1970 was about 56 million gallons for both processes.

TABLE B.1.1

CHLORO-ORGANIC COMPOUNDS
Estimate of Production for 1970

		Plants△			
			Capacity (MM gallons)		
Category	Compound	No.	Largest	Range of Remainder	Production Volume* (MM Gallons)
C_1	Methyl Chloride	13	13	<1-10	56
	Methyl Bromide	–	–	–	<2
	Methylene Chloride	9	8	2-7	37
	Chloroform	8	6	0.5-2.5	19
	Carbon Tetrachloride	10	15	1-10	76
	Trichlorofluoromethane	–	–	–	20
	Dichlorodifluoromethane	–	–	–	30
C_2	Ethyl Chloride	8	36	3-13	90
	Ethylene Dichloride	15	100	8-85	620
	Vinyl Chloride	14	115	20-80	540
	Methyl Chloroform	4	36	5-12	34
	Trichloroethylene	10	22	2-7	49
	Perchloroethylene	14	16	1-8	56
C_3	1,3-Dichloropropene	–	–	–	~10
Aromatics	Chlorobenzene	12	40	0.5-8	70
	Dichlorobenzenes	14	–	–	30
	Trichlorobenzenes	4	–	–	<5

△ Arthur D. Little, Inc., estimates.

* Taken from "Synthetic Organic Chemicals, U.S. Production and Sales, 1970, "U.S. Tariff Commission TC Publication 479.

The reaction of methanol and hydrochloric acid leads to methyl chloride, methylene chloride and water. Although the process yield of desired component is usually greater than 90% based on the initial HCl, most of the unreacted HCl leaves the process as an HCl – H_2O stream containing methyl chloride and/or methylene chloride. The waste organics probably represent no more than 1–2 percent of the final product so even in the largest plants, concentrated waste organics would amount to less than 200,000 gallons. However, since these compounds exist from the process mixed with large volumes of aqueous hydrochloric acid, the waste stream volume could reach 40 million gallons per year in a few isolated cases.

The production route which uses chlorine and methane should not lead to any large waste streams. After chlorination, the product is distilled; low-boiling fractions are recycled and pot residue is used to make perchloroethylene. Because of the need to condense the desired product, some water is produced that contains hydrochloric acid, but mostly this stream is pretty clean and can be sold as a commercial product. (Some is waste but large volumes are not common.)

Other Chloromethane Products. These products include methylene chloride, chloroform, and carbon tetrachloride. They are made via the chlorination of methane and most plants that make one compound make all three. Each product is made in roughly 10 plants with geographical distribution similar to those for methyl chloride. Plant capacities range from 2 million to 8 million gallons per year for chloroform and 1 million to 15 million gallons per year for carbon tetrachloride.

As with methyl chloride, the only potential waste stream is the water used to aid condensation and this water tends to be fairly clean. In fact, the trend is away from direct contact between product and water so even less water probably will be used. Impure product is distilled and recycled, or used to manufacture perchloroethylene.

C_2 Compounds. In this category there are several plants where the waste volumes are sufficiently large to justify having waste processing facilities on site. Solvents included in this group are: ethyl chloride, ethylene dichloride, vinyl chloride, methyl chloroform, trichloroethylene, and perchloroethylene.

Ethyl Chloride. Ethyl chloride can be made by chlorination of ethane, reaction of HCl and ethanol, or addition of HCl to ethylene. This last is the primary process. The eight plant locations include five on the Gulf Coast, one in Virginia, one in New Jersey and one on the West Coast. Capacities are 3-30 million gallons per year and total production for 1970 was 90 million gallons.

The discussion for methyl chloride applies here for the two processes that are common to both. The plants based on ethanol have capacities of less than 15 million gallons per year so similar maximums for waste volumes can be anticipated. The reaction of ethylene with HCl should not lead to large waste-water streams, and as with chlorination, the pot residue can be utilized to make perchloroethylene.

Ethylene Dichloride. Because it is an intermediate for many other chloro-organics, this is the largest single chemical consumer of chlorine, including vinyl chloride and thus vinyl chloride polymer. Two basic processes are used – chlorination of ethylene or oxychlorination ($HCl + O_2$) of ethylene. Within the 15 or so plants, capacities can be large (up to 100 million gallons per year). Total production for 1970 was 620 million gallons.

For the process based on reaction of HCl with ethylene almost all the waste goes into trichloroethylene or perchloroethylene production. The oxychlorination reaction requires a separation to remove the water produced during the reaction. These resulting water streams, which contain traces of organics, can be very large – hundreds of millions of gallons per year. Thus, this process represents a possible situation where on-site processing may be attractive – but the initial processing step would have to be seperation (not incineration) because the chloro-organics are present at only the parts per million level. Most of the product ethylene dichloride is used to make vinyl chloride and the processes are interrelated so the HCl is recycled.

Vinyl Chloride. As noted above, most of the vinyl chloride is made by pyrolysis of ethylene dichloride with resultant recycling of the non-vinyl chloride stream. Therefore, little chloro organics show up as a waste stream even though the production quantities are huge (as high as 115 million gallons/year in one plant).

Methyl Chloroform, Trichloroethylene, and Perchloroethylene. These compounds are produced by interaction of HCl with other organics under appropriate thermal conditions. Waste from methyl chloroform goes to the perchloroethylene plant; the ultimate waste product from trichloroethylene and perchloroethylene is a solid high-melting material that can be burned or buried.

C_3 Compounds. 1,3-Dichloropropene and 1,2-dichloropropane are obtained by upgrading allyl chloride to a more saleable product. Total production for 1970 was about 10 million gallons so total waste streams are not likely to be over a few million gallons at the most.

Aromatic Compounds. The aromatics of interest to this program are: mono-, di- and trichlorobenzenes. Of these, mono is by far the largest (70 million gallons and 12 plants). Dichlorobenzenes are produced in a similar number of plants but total production in 1970 was near 30 million gallons. The total for trichlorobenzene amounted to less than 5 million gallons in 1970.

In making chloroaromatics, almost 98% of the HCl used in the oxychlorination process ends up in the final product. Thus, only 2 to 3 percent of the HCl ends up in the exit wastewater stream and most of this is as HCl. However, this waste stream will be saturated in chlorobenzenes. One very large producer may have a waste volume greater than 40 million gallons/year, but the rest should be well below 10 million gallons/year.

Uses of Chloro Organic Solvents. The major uses and estimated volumes for the chloro organic solvents are given in Table B.1.2. By and large, they fall into three general categories:

- A component in a manufacturing process;
- A solvent for a manufacturing process; or
- A solvent or vapor degreasing operation.

Most of the applications of these solvents consume in total, less than 20 million gallons of solvent a year. In addition, in most cases, this total volume is distributed among several locations, so except for the situations listed below, there is little chance that a user will have more than a maximum of 10-20 million gallons of waste a year. Those where large volumes might be found include:

- Production of fluorocarbon – carbon tetrachloride.

- Production of tetraethyl lead – ethyl chloride. However, because this material is unstable when exposed to water, aqueous waste streams are not feasible. Organic waste streams from this process should be well below the 30-million-gallon-per-year level.

- Production of vinyl chloride – ethylene dichloride.

- Production of polyvinyl chloride – vinyl chloride.

- Vapor degreasing – trichloroethylene. Although total quantities in the United States probably are huge, the final waste usually is a sludge or spent solvent and involve low volumes per unit operation (500 gallons or less).

- Dry cleaning – perchloroethylene. These tend to be numerous and small-volume operations.

Thus, a few situations may involve large-volume waste streams, but most users of organo chlorine wastes will have waste quantities well below the breakoff limit of tens of millions of gallons.

Pesticides

The pesticide industry is composed of a few producing plants, a large number of formulators and a great number of applicators. Only a cursory examination of the pesticide industry was conducted. However, it is clear that although there may be a few large waste producers, most of this industry will have waste streams well below the volume where it is economically attractive to treat on-site.

TABLE B.1.2

ESTIMATED END USE

		Principal Usage		Secondary Usage		Other Uses	
Category	Solvent	Area	1970 Volume (gal x 10^6)	Area	Volume (gal x 10^6)	Area	Volume (gal x 10^6)
C_1	Methyl Chloride	Silicones	15	Tetramethyl Lead	14	Rubber	11
	Methylene Chloride	Paint and Varnish Removers	11	Solvent Degreasing	4	Other	8
	Chloroform	Fluorocarbon Plastics	9	Fluorocarbon Refrigerants	8	Other	1
	Carbon Tetrachloride	Production of Fluorocarbon 12	39	Production of Fluorocarbon 11	18	Other	10
C_2	Ethyl Chloride	Tetraethyl Lead	72	Styrene Manufacturing	6	Other	10
	Ethylene Dichloride	Vinyl Chloride	557	Ethylene Amines	28	Other	27
	Vinyl Chloride	Polyvinyl Chloride	470	—		—	
	Methyl Chloroform	Cold Cleaning	22	Vapor Degreasing	5	Other	6
	Trichloroethylene	Vapor Degreasing	43	Other	4	—	
	Perchloroethylene	Dry Cleaning	40	Fluorocarbons	5	Other	2
C_3	1,3-Dichloropropene						
		Fumigants, degreasing, solvent, intermediate chemical.					
	1,2-Dichloropropane						
Cyclic	Monochlorobenzene	Phenol	36	Chloronitrobenzene	20	DDT	10
	Dichlorobenzenes	Moth Control	4	Other	8	—	

The number of plants producing the pesticides included as Category I wastes, along with production volumes and waste quantities, is given in Table B.1.2A. This data shows that only a few plants in the United States produce these chemicals and that none of their waste streams would amount to more than 5 million gallons per year. Only three of the plants are located in the Pennsylvania-New Jersey area.

Although detailed data was not developed on the numbers of formulators and applicators in the United States or within the Pennsylvania-New Jersey area, it is assumed that the total is fairly large. For example, Newark and Philadelphia have a combined total of over 200 listings for exterminators, fumigators and pest control companies. Obviously, many of these are extremely small operations, but the main point is still valid – there is a large number of potential sources for pesticide wastes. In no instance will an individual company be generating large (more than one million gallons) volumes of waste. Normal business practice would not permit 20% total wastage.

In addition to the pesticide wastes generated by the industry during its normal operations, there are growing amounts of waste product due to the collection and storage of used or aged pesticide containers. In this evaluation, these collection depots have been assumed to be off-site processors so that these wastes already fit the "process off-site" classification.

Paints

The U.S. paint industry is a source of waste sludge that contains a variety of heavy metal compounds including three based on lead, cadmium, and chromium. The manufacture of paint contributes a relatively modest amount of sludge for disposal. In total, this probably approximates six million gallons per year. On the basis of 1970 pigment consumption by the coating industry, this sludge contains over 600,000 pounds of lead pigments, 150,000 pounds of chromium pigments, and about 5,000 pounds of cadmium pigments.* About 1700 establishments most relatively small, make paint.

The amount of waste generated by the production of paint is modest compared to the paint sludge that originates with spray paint operations which utilize production finishes. We estimate that close to 100 million gallons per year of paint sludge are generated through spray painting. The pigment content per gallon is lower than that of the sludge from paint manufacture both by virtue of the method of generating the sludge and the types of paints used for industrial product finishes. Nevertheless, the total poundage of heavy metal pigments produced as wastes from spray painting operations is quite probably an order of magnitude larger than the pigment contained in wastes from paint manufacture. Also, considerably more locations undoubtedly use paint than produce it, so from the point of view of number of locations, the paint industry will probably provide a hundred or more for each national treatment facility.

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*TRW 11th Monthly Report.

TABLE B.1.2A

Production of Pesticides

	Number of Plants[a]		Total 1970 Production[b] (pounds x 10^6)	Maximum Possible Waste Volume (gallons x 10^6/yr/plant)	
	Total U.S.	N.J./Pa.		ADL[d]	TRW[e]
Aldrin Group			89	10	
Aldrin	1	--			1
Chlordane	1	--			2.5
Dieldrin	1	--			<0.1
Endrin	2	--			<1
Heptachlor	1	--			0.6
(Toxaphene)	--	--			
Benzene Hexachloride	2	--	(c)	0	--
2,4-D	8	1	44	5	5
DDT	8	3	59	5	4.5
Methyl Bromide	6	--	21	1	2.2
Methyl Parathion	7	--	41	5	4.5
Parathion	7	--	15	2	1.5
Demeton	1	--	(c)	--	--
Guthion	--	--	(c)	--	0.4
Dinitro Cresols	1	--	(c)	--	0.4
Total	46				

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a - Based on 1969-1970 information
b - U.S. Tarriff Commission, U.S. production and Sales of Synthetic Organic Chemicals, 1970, pp. 198-199.
c - No production reported.
d - ADL estimate, purposely made on high side.
e - Includes methyl chloride and ethylene bromide.

Paint Industry Wastes. Total pigments consumed by the coating industry in 1970 are given in Table B.1.3. The inorganic pigments – which include compounds of lead, chromium, and cadmium – are principally responsible for the toxicity of paints and paint sludges. Table B.1.4 describes the most commonly used pigments that contain toxic ingredients.

Paint waste also contributes modest amounts of other toxic materials added to improve stability or performance. These include phenyl mercury compounds, used as a mildewcide. These compounds are used virtually only in water base paints in very low concentration. During 1971, about 600,000 pounds of mercury were consumed by the paint industry.* In addition, modest amounts of other toxic materials, such as lead-based dryer additives, are used in the manufacture of solvent-based paints. The contribution of heavy metal compounds to the paint by these additives is modest, however, compared to the amount of heavy metal compounds present in the paint as pigments.

As a consequence of paint manufacture, toxic wastes are produced in the form of: a) finished paint which is insoluble for whatever reason; and b) waste from washing and cleaning operations. Waste contained in wash solvents is eventually concentrated either by settling or, in the case of solvent paint, by settling and distillation.

Industry sources indicated a very wide range of waste in actual practice – from one gallon of sludge per 60 gallons of finished paint for a large plant with varied output to as little as one gallon of sludge per 500 gallons of paint for small plants manufacturing a high proportion of the same product. There is a strong inclination, particularly among the smaller producers, to utilize every bit of raw material possible and, with continuous batch production of the same product, washings normally go into subsequent batches.

Generally speaking, there is more waste in the production of latex paint; we have estimated that one gallon of the sludge is obtained from the decantation and solvent recovery operations for every 120 gallons of solvent based paint produced. This value is in agreement with TRW's 11th Monthly Report.*

Wastes from paint manufacture, both as sludge and finished paint, are normally drummed and disposed of in landfill operations, but local regulations are making this practice more and more difficult. There is an increasing dependence on disposal contractors who are paid to haul wastes away and assume responsibility for disposal. In the past there has been a continuous tendency for a small paint plant to "store" its wastes for future use. This practice has probably grown in recent years because of the problems presented by disposal. Storage is used primarily with solvent paint systems since latexes do not mix and store well.

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*TRW 11th Monthly Report, Contract No.

TABLE B.1.3

PIGMENTS CONSUMED BY THE COATINGS INDUSTRY – 1970*

	Millions of lb
White pigments:	800
Titanium dioxide	800
Zinc oxide – lead free	50
Zinc oxide – leaded	10
White lead	10
Other	5
Total	875
Colored and black pigments:	
Carbon blacks	15
Red lead	20
Chrome green	5.4
Chrome oxide green	10.4
Chrome yellow and orange	63.5
Molybdate chrome orange	21.7
Zinc yellow	15.6
Iron blue	10.0
Cadmium red, yellow, and orange**	0.7
Other inorganic colors	116
Organic colors	12
Metallics (aluminum pastes, etc.)	20
Zinc dust	50
Total	367
Extenders:	
Calcium carbonate	350
Magnesium silicate (talc)	330
Clay	280
Barium sulfate (barytes)	100
Mica	60
Others	200
Total	1,320
Total pigments and extenders	2,562

**Taken from TRW 11th Monthly Report, Contract No.

**The estimates are based on the assumption that 25 percent of the cadmium pigments produced is consumed by the paint industry. Consumption figure of 0.7 million lb is as the cadmium metal. About 51,000 lb of selenium are used in the cadmium pigments.

TABLE B.1.4

PIGMENTS CONTAINING TOXIC INGREDIENTS*

Pigment	Toxic Ingredient
White lead	lead
Leaded zinc oxide	lead
Red lead	lead
Cadmium yellow	cadmium
Cadmium orange	cadmium, selenium
Cadmium red	cadmium, selenium
Chrome yellow	lead, chromate
Chrome orange	lead, chromate
Zinc yellow	chromate
Molybdate orange	lead, chromate
Chrome green	lead, chromate, cyanide
Chrome oxide green	chromium oxide
Iron blue	cyanide

*Taken from TRW 11th Monthly Report, Contract No.

During 1970, 830 million gallons of surface coating materials were produced in the United States. Of this total, 540 million gallons are estimated to have been solvent-based and 290 million gallons water-based paints. On the basis of our previous assumptions of one gallon of sludge generated for every 170 gallons of water-based paint and for every 120 gallons of solvent-based paint, on average, the manufacture of paint generated approximately six million gallons of sludge per year on a national level.

As shown in Table B.1.5, the paint industry is not concentrated very highly; it is characterized by a large number of small plants with relatively small annual production. Of the 1700 establishments listed by the Bureau of Census in 1967, only an estimated 10 of these produced more than 10 million gallons of paint per year, while over half of them produced less than 200,000 gallons per year. Consequently, the six million pounds of paint sludge produced annually are dispersed broadly over a number of small producers. As shown by Table B.1.5 more than 1000 of the 1700 establishments would produce less than 1500 gallons of sludge per year. Even the largest producers will generate a relatively modest amount of sludge for which they have no totally satisfactory means of disposal.

The paint industry in Pennsylvania and New Jersey includes 266 manufacturing establishments, or 15.6 percent of the nation's total paint producing plants in 1967. These plants, however, are somewhat larger than the national average. In 1967, the average U.S. paint plant shipped products valued at $773,000. In Pennsylvania and New Jersey the average in that year was almost three times as great at slightly less than $2 million of product. Pennsylvania and New Jersey, therefore, appear to represent a geographic area in which the disposal of toxic waste from paint manufacturing would be a significant problem.

Spray Painting Wastes. Industrial spray painting generates significantly larger quantities of toxic paint waste than does the manufacture of paint. In 1970, an estimated 330 million gallons of product finishes were produced and the great majority of these finishes, perhaps as high as 90 percent, were applied by spray painting.

We estimate that on average, one gallon of sludge is generated for each three gallons of product finish supplied by spray painting. It is believed, therefore, that industrial spray painting generated about 100 million gallons of sludge in 1970.

Paint loss in the spray painting process varies tremendously, the amount depending on the objects being painted and the technique used. Electrostatic painting techniques and the use of airless equipment tend to reduce loss, and in some instances, losses are as low as 10 percent of the total paint utilized. When objects with small surface areas (compared to the total spray pattern) are being painted, losses can run as high as 80 percent of the total paint utilized. Normally, any spray that does not adhere to the object being painted moves into a water-wash spray booth and is carried down as sludge. This sludge is then scraped off or skimmed off and put in barrels for disposal.

TABLE B.1.5

Estimated U.S. Paint Sludge Production By Company Size

(thousand gallons/year)

Number of Establishments	Per-Plant Paint Production	Per-Plant Sludge Production
468	24	.17
242	81	.58
311	171	1.2
350	382	2.7
171	400	2.9
113	2,090	15
36	4,600	33
8	10,900	78
2	25,400	180

SOURCES: 1967 Census of Manufactures and Arthur D. Little, Inc., estimates.

Spray painters have the same disposal problem as paint manufacturers. Normally, the company performing spray painting will pay a contractor to pick up the barrels of sludge and he in turn disposes of it in landfill projects.

Spray painting, and consequently generation of paint sludge, is even more widely dispersed than the manufacture of paint. Producers of automobiles, wood furniture and fixtures, metal containers, metal furniture and fixtures, appliances, machinery and equipment, factory finished wood and non-automotive transportation are all major users of product finishes applied by spray painting. Paint sludge is quite probably generated in tens of thousands of individual locations and in individual amounts varying from hundreds of gallons per year to hundreds of thousands of gallons per year.

It is estimated that Pennsylvania and New Jersey are also major producers of waste paint sludge from spray painting. These two states accounted for close to 12 percent of the total value of shipment of manufactured goods as reported by the Bureau of Census. Our best estimate is that the generation of spray painting waste would be proportional to the national figure on the same basis and that Pennsylvania and New Jersey would generate about 12 million gallons of spray painting sludge annually.

All of the spray painters face the same problem of disposal in varying degrees. As with the paint industry itself, there is no satisfactory means of handling spray paint wastes. Wastes discarded in landfill operations often contain toxic ingredients that could lead to contamination of ground water and soil. As it becomes more broadly recognized and rigidly controlled, the industry faces increasing problems of disposal without, as yet, any satisfactory solution.

WASTES CONTAINING HEAVY METALS AND/OR CYANIDES

All Category I metal-containing wastes are included here except: wastes that are primarily organic but also contain metals (paints, pesticides, etc.), and sludges with organics. The industries that generate most of these wastes are: tanneries, metal finishing, batteries, mining and smelting, cooling towers, and chloroalkali plants.

With the metal-containing waste streams, three basic waste forms were considered: dilute heavy metals, concentrated heavy metals, and dilute heavy metals containing organics.

Sources with dilute metal wastes will be found in many industries such as: metal finishing, tanning, battery production, refining, etc. In most cases, the volumes of water are well above one million gallons per year so that on-site treatment should be attractive. In our field study, only a few sources were identified as ones which might ship the dilute aqueous waste (two metal finishing, no tanneries, and possibly one battery manufacturer). However, a large number of potential sources were identified as having a potential need for sending sludge or concentrated wastes to a central processor (300 metal finishing plants, 70 tanneries, plus many cooling towers, several dozen smelters, etc.).

Electroplating

Industry Statistics. The electroplating metal finishing industry is divided into two major segments, contract or job finishing plants which primarily process material owned by others and captive plating plants set up in manufacturing establishments for finishing their own products. Although no exact figures are available, the two segments are considered to be about equal in number of establishments. The latest data available on the contract portion of the industry are for the year 1967 (Table B.1.6). Data for 1972 are being compiled by the Commerce Department but will not be published until 1974. In 1967 the total number of contract establishments reported was 3235, of which 853 had 20 or more employees. From the growth rate indicated from the 1958 and 1963 census, we believe the total number now is in the order of 3500, of which about 1000 employ at least 20 people.

No equivalent statistics are available on captive plants but assuming the job plating shops are one-half the total, we estimate the United States has 7000 plating plants – contract and captive – at present. (Other estimates placed the total in 1968 at 15,000 to 20,000 facilities,* but we have chosen to use the more conservative number.)

From a review of the plating establishments in the New Jersey and Pennsylvania area, and extrapolating from the 1967 census, we estimate that in 1972 New Jersey had 162 job plating shops and Pennsylvania 134. Of these 49 and 40, respectively, employed more than 20 people.

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*State-of-the-Art Review of Metal Finishing Waste Treatment, Water Pollution, Control Research Series 12010EIe 11/68. U.S. Department of Interior, Federal Water Quality Administration.

TABLE B.1.6

Number of Establishments by Geographic Area

Plating and Polishing. SIC Code 3471

Geographic Area	Total Establishments	Establishments with 20 employees or more
Total U.S.	3235	853
East North Central	1098	321
Middle Atlantic	680	168
Pacific (including Calif.)	548	137
Pacific (California only)	502	127
New England	367	96
South Atlantic	157	32
West South Central	138	32
West North Central	129	33
East South Central	67	21
Mountain	51	13

SOURCE: U.S. Department of Commerce, U.S. Census of Manufactures, 1967

We have assumed that the materials and volumes of wastes generated in job shop operations are quite similar to those encountered in captive plants although there may be more extremes in the size of parts plated in the captive plants – from common pins to large rolls of sheet stock. The total effluent volumes, therefore, will be double that calculated for contract plating shops.

Source and Character of Plating Wastes. The most important source of plating wastes is the rinse water which is used after every processing step in the plating cycle. Since water usually flows constantly through the rinse tanks, the volumes involved are very large and transportation to a central disposal facility without concentration of some kind seems impractical except for the very smallest units. Historically, very large volumes of rinse waters were used by platers to ensure quality finishes and to dilute contaminants to an acceptable level, and little attention was paid to conserving water. In the last decade, however, water conservation and treatment of effluents to remove contaminants have become necessary not only for economic reasons but because of environmental concerns and pressures. The emphasis today, therefore, is on saving water through counter-current rinsing and recycling techniques and some compromise with the quality of finish – which is affected by rinsing – has to be tolerated.

The composition of waste rinse waters may vary widely from shop to shop and even from hour to hour in the same shop, particularly in the smaller facilities. For instance, information from five plating plants shows variations in concentrations of cations in their rinse water of: 15-300 ppm Zn, 5-22 ppm Cr, and 10-100 ppm Cd. Many other cations – such as Ni, Cu, Pb, and Al – are present in variable amounts in most effluents depending on the metals being treated. Although strictly not in this category, cyanide is an integral part of the plating industry. It will vary from 0 to 500 ppm depending on the bath. Sludges from filters in the operating cycle and from the treatment of waste rinse water represent another significant source of concentrated wastes which may be even more variable in composition than rinse water.

We have attempted to estimate within an order of magnitude the sludge volume which might be produced as a function of rinse water volume. Much of these sludges eventually is transported from the plating plant, either directly after consolidation by filtering, settling or centrifuging, or after settling in outdoor lagoons or ponds for extended periods.

Another source of wastes is the discharge of plating or finishing baths from the plant into the effluent, either intentionally or by accident. If a treatment plant is provided, the contaminants are removed and eventually end up in the sludge. In most cases, it would be practical to ship the discarded concentrated plating baths to a central disposal area since the volumes are relatively small.

Other sources of wastes are equipment cleaning, vent scrubber waters and concentrated regenerants from ion exchange units. These materials also probably would end up in the sludge of a treatment plant, although they could be segregated and shipped to a disposal area.

Treatment of Wastes. Rinse waters which are to be purified and generally segregated into at least three streams: cyanide containing wastes, chromate wastes, and waters containing other heavy metal ions. The latter streams may be combined with acid-alkaline waste streams to neutralize and precipitate the metal hydroxides. Waste treatment details for these materials are well covered in the literature and will not be repeated here.* If rinse waters were to be transported to a central processing station, the same separation of streams still would be required.

Although the shipment of large volumes of dilute wastes seems impractical, some combination of segregation, concentration and recycle might be less costly than complete treatment at the plating plant. A complete recycle of water and chemicals by evaporative recovery or possibly by reverse osmosis seems a possible answer to waste control in the plating industry, but this approach is not feasible or economic for all plating baths or for all installation sizes. Impurity build-up is an important factor to be considered in applying complete recycle of plating material and wastes. Complete recycle of plating drag-out and rinse water appears applicable to only a few more favorable situations and some contaminated effluents will always be discharged from the average plant. However, as contaminant limits are regulated more severely, the destructive methods of control will become more expensive and perhaps not applicable, so recycling will become more attractive. Unless transportation and treatment costs at central stations can be made competitive, it appears the trend will be toward more and more recycling and reuse of rinse waters. Therefore, the installations of large central process stations that might depend on plating wastes should take into account these trends.

Because of the high cost of cyanide destruction plating companies are turning more and more to non-cyanide type plating baths. For instance, there is a definite trend away from the high cyanide zinc bath to either a low cyanide composition or an alkaline or acid type bath without cyanide. The same trend is noted with respect to cadmium and gold plating. Therefore, the volume of cyanide wastes emanating from metal finishing plants is bound to decrease at an accelerated pace. Complete elimination of cyanide is much further away since no practical substitutes for the widely used cyanide copper strike on steel or zinc-base diecasting basis metals, nor for plating brass, bronze or silver have been developed.

Volume of Effluents in the New Jersey – Pennsylvania Area. As noted above, we estimate there are 296 job plating shops in the New Jersey and Pennsylvania area divided as shown on the following page.

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*Ceresa, M., and Lancy, L.E., "Waste Water Treatment," Metal Finishing Guidebook and Directory for 1972, Metals and Plastics Publications, Inc., Westwood, N.J., pp. 761-783.

	Total Establishments	Plants Having 20 or More Employees
New Jersey	162	49
Pennsylvania	134	40

From a review of rinse water volume data from 30 small, medium, and large plating facilities (Table B.1.7) we estimated the median volume of rinse waters in the larger plants to be 20,000 gallons per hour and 4,000 gallons per hour in the remainder. Rinse water volumes in individual plants ranged from 960 to 318,000 gallons per day. The total rinse water volume from all job shops in these two areas, therefore, would be about 21 million gallons per 8-hour shift.

A review of the volume of rinse waters containing chromates and cyanides produced in 15 captive plants is given in Table B.1.8. Most of these plants were considerably larger than the job shops we reviewed, but the average water volume was about the same, 20,000 gallons per hour (for large shops). Assuming about the same distribution of small, medium, and large captive plants as job shops, the total rinse water volume in the New Jersey and Pennsylvania area is on the order of 40 million gallons per day.

Data from one plant provided some indication of the sludge volume which may result from treatment of waste water containing Cu, Ni, Cr, Cd, Zn, Pb, and cyanide contaminants. The rinse water volume in this plant was about 12,000 gallons per day and it accumulated 50 to 75 gallons per day of sludge containing 17 percent solids. This is equivalent to 0.4 – 0.6 percent of the total rinse water. Using a range of 0.05 to 0.5 percent for the total sludge volume that might be expected from treatment of all the rinse water in New Jersey and Pennsylvania plating plants, we estimate total volume of sludge from the rinse water from both job shops and captive plants would be 21,000 to 210,000 gallons per day. Volumes from individual plants might range from less than a gallon to 5,400 gallons per day.

The Tanning Industry

Character of the Industry. The hazardous material found in tanning effluents is chromium. The 1967 Census of Manufactures lists 519 leather tanning and finishing establishments, of which only 258 employ more than 20 persons. The total industry employment is given as 30,700, including 26,400 production workers. While the number of tanneries has undoubtedly declined since the 1967 Census, the geographical distribution indicated in Table B.1.9 is probably still valid.

The chrome tanning process is used in virtually all tanneries at present. The major exception to chrome tanning is sole leather, most of which is still vegetable tanned. One West Coast tannery does vegetable tanning exclusively, and a few small specialty operations use other types of tanning. Deerskins, for example, may be oil tanned, and a Tennessee

TABLE B.1.7

Rinse Water Volumes in Contract Plating Shops from Literature and ADL Surveys

Plant No.	Rinse Water Volume (gal/8-hr day)	Rinse Water Contaminants*	Sources of Information
1	960	Ni 25 (sludge volume 6 gal. every 2 weeks)	1. "Which Pollution Control System?" Product Finishing, 37, 3, 162 (December, 1972).
2	2,000	—	2. ADL Private Communication.
3	3,600	Zn 300 Cd 100, Cu 50	3. Gallo, B.R., and Culotta, J.M., "Economics of Evaporative Recovery of plating Waste and Harvey-Hubbell." AES Waste Waste Treatment Conference, May 21-22, 1971, Post Junior College, Waterbury, Conn., American Electroplaters' Society New England Council.
4	4,000	Cu 100, Cr, Cd, Ag, CN	4. Litt, "A Small Plant Can Treat Wastes Economically," Metal Finishing, 69, 11, 52 (November, 1971).
5	4,800	Zn 300 CN 130, Pb 18, Cu 15, Cd 10	5. Crawford, W.R., "Meeting Pollution Regulations in Chicago," Finishers' Management, 17, 8, 7 (August 1972).
6	7,500	Cu, Ni, Cr, Zn, Cd, Ag, Sn, CN	6. ADL Private Communication.
7	12,000	Cu, Ni, Cr, Pb, Cd, Zn, CN (Daily sludge volume 50-75 gal, 17% solids)	7. "Which Pollution Control System?" op. cit., p. 164.
8	16,000	Cu, Cr, Sn	8. Pinner, R., "Cost Factors for Effluent Treatment and Recovery of Materials in the Metal Finishing Department," Electroplating and Metal Finishing, 24, 3, 16 (March, 1971).
9	19,200	Cr 30-250	9. Anderson, J.P., Peterson, G.K., and Massion, P., "Demineralization for Rinse Water Reclamation," Finishers' Management, 16, 7, 21 (July, 1971).
10	28,800	Ni, Cr, Zn, CN	10. "NAMF Protests EPA Pollution Guidelines," Finishers' Management, 17, 9, 11, (September 1972).
11	31,200	—	11. ADL Private Communication
12	32,800	Ni, Cr, Zn, PO_4	12. Pinner, R., op. cit., p. 18.
13	40,000	Cr (12,000 lb CrO_3 recovered/month)	13. "Which Pollution Control System?" op. cit., p. 158.
14	60,000	Cu, Ni, Cr, Cd, Zn, Ag, Au, CN (Assume 1/2 CN, 1/2 other)	14. ADL Private Communication.
15	72,000	Cr 5, Cn 10 (24,000 Cr, 48,000 CN)	15. "Which Pollution Control System?" op. cit., p. 162.
16	78,000	—	16. Lancy, L.E., Nohse, W., and Wystrach, D., "Practical and Economic Comparison of the Most Common Metal Finishing Waste Treatment Systems," Plating, 59, 2, 129 (Feb., 1972).

TABLE B.1.7 (Continued)

Plant No.	Rinse Water Volume (gal/8-hr day)	Rinse Water Contaminants*	Sources of Information
17	80,000	Cu, Ni, Cr, Zn, Ag, Al	17. Pinner, R., op. cit., p. 17.
18	80,500	Cr 22, CN 19, Cu 0.5, Zn 15	18. Lauber, T.C., "A Case History in Pollution Control," Finishers' Management, 16, 11, 7 (November, 1971).
19	96,000	Cu, Ni, Cr	19. "NAMF Protests EPA Pollution Guidelines," op. cit.
20	102,000	Cu, Ni, Cr	20. Lancy, et. al., op. cit.
21	106,000	Cu, Ni	21. Lancy, et. al., op. cit.
22	120,000	Cr, PO_4 alkalies	22. "Ford Tests Sludge Solidification," Products Finishing, 36, 4, 55 (January, 1972).
23	120,000	CN 150-500	23. "Which Pollution Control System?" op. cit., p. 159.
24	150,000	---	24. Lancy, et. al., op. cit.
25	160,000	Cu, Ni, Cr, Zn, CN	25. Pinner, R., op. cit., p. 16.
26	160,000	Cu, Ni, Cr.	26. Ibid.
27	160,000	Cu, Ni, Cr, Al, CN	27. Ibid.
28	191,000	Cu, Ni, Cr	28. Lancy, et. al., op. cit.
29	220,000	---	29. ADL private communication.
30	318,000	Cu, Ni, Cr, Zn, Cd	30. Lancy, et. al., op. cit.

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*Number after element refers to concentration in parts per million.

TABLE B.1.8

VOLUMES OF CHROMIUM AND CYANIDE-BEARING WASTES FROM TYPICAL PLATING OPERATIONS IN THE ELECTROPLATING INDUSTRY*

	Chromium-Bearing Waste				Cyanide-Bearing Waste				
	Volume,	Analyses, ppm[a]			Volume,	Analyses, ppm[a]			
Type of Work Plated	(gal/day)	Cr	Ni	Cu	(gal/day)	CN	Cu	Zn	Cd
Aircraft engines and parts	440,600	–	–	–	293,760	–	–	–	–
Automobile bumpers	480,000	–	–	–	–	–	–	–	–
Automobile grills	100,000	700	–	–	–	–	–	–	–
Missile parts	80,000	1	–	–	32,000	80	–	–	–
Office furniture	24,000	–	–	–	–	–	–	–	–
Typewriters and office machines	50,000	16	39	–	–	39	–	–	–
Instrumentation and control equipment	–	–	–	–	13,000	–	–	–	–
Electronic hardware	828,000	–	–	–	259,200	200-1,500	–	–	–
Home appliances	43,200	–	–	–	108,000	–	–	–	–
Television antennaes	–	–	–	–	11,000	–	–	–	–
Silverware	40,000	5	33	135	165,000	172	18	11	–
Instrument motors and electric clocks	112,000	–	–	–	–	–	–	–	–
Automobile manufacture	620,000	30	80	70	410,000	204	–	113	–
Unspecified	–	–	–	–	–	–	–	–	–
Metal fastener plant	89,000	52	302	–	–	–	–	–	–

*A State-of-the-Art Review of Metal Finishing Wastes, Water Pollution Control Research Series 12010 EIE, 11/68, U.S. Dept. of the Interior, Federal Water Quality Administration, p. 20.

(a) Analyses not shown are not available.

TABLE B.1.9

Geographical Distribution of U.S. Tanneries

Region	State	No. of Tanneries		No. of Employees	
New England		183		9,700	
	Mass.		146		5,900
Middle Atlantic		176		6,700	
	N. Y.		108		2,500
	N. J.		48		2,300
	Pa.		20		1,900
East North Central		74		8,200	
	Wis.		30		4,400
	Ill.		19		1,700
West North Central		13		800	
South*		47		4,600	
West		26		800	
	Cal.		15		700
		Total 519			

*Small tanneries are located throughout the south in Del., Md., Va., W. Va., No. Car., Ga., Ky., Tenn., and Texas.

SOURCE: U.S. Department of Commerce, Census of Manufactures, 1967.

tannery which manufactures a very white leather for baseballs uses zirconium tanning. In 1967, the value of all tanned and finished leather was $846.2 million, while that of vegetable tanned sole leather was $86.7 million, or roughly 10 percent of the total.

Source and Character of the Waste. Hides are normally received in the green-salted condition. They are salted at the slaughterhouse, stacked, and tied with twine for shipment. The chrome tanning process is shown schematically in Figure B.1.1. All operations up to and including the chrome tan step might typically be done in a single cylindrical rotating mill, 10 feet long and 10 feet in diameter. The mill is loaded with about 9,000 pounds of hides, and the required solutions for each operation are added successively and drained out when that operation is completed.

As indicated in the flow diagram, the hides are washed and soaked to remove blood, dirt, dung and free salt and to soften the hide. Muscle and fatty tissues are removed mechanically in the fleshing operation, if necessary. In modern practice, the green-salted hides have already been fleshed. For the liming operation, a suspension of lime hydrate and alkaline reducing agents, such as Na_2S, and amines, as accelerators, is introduced to loosen the hair and epidermis and to remove grease. In "bating," a solution of proteolytic enzyme (pancreatin or trypsin) and an acid salt (e.g., $[NH_4]_2SO_4$) are introduced to remove absorbed lime and to hydrolyze undesirable proteins. Pickling involves a soak in 0.75 percent H_2SO_4 and 5-8 percent NaCl to bring the hides to the acid condition necessary for absorption of chromium. Finally, the chrome tanning solution, typically a basic chromic sulfate or chromic chloride, is added on balance. The wastes from the processes described up to this point are alkaline. The coloring and fat liquoring are done in acid solutions. A separate mill is typically used and the waste stream is kept apart from the alkaline tanning wastes.

Treatment of the Waste. At present, waste streams are either allowed to flow untreated into a municipal system (or other water receiving system) or the chromium is precipitated and landfilled. The latter may be a separate operation or an addition to a municipal (or private) landfill facility.

Volume of Effluent. About 1,000 pounds of hides are tanned per mill, with a total water volume of 8,000-10,000 gallons being consumed in the process. Assuming segregation of the chromium effluent, the volume of hazardous waste would be about 4,500 gallons per 1,000 pounds of hides. If the chromium effluent is not segregated (as is the case more often than not), the volume of waste would be 9,000 gallons per 1,000 pounds of hides. In the simplest case, therefore, where a tannery operates one mill daily, the daily waste effluent would be either 4,500 or 9,000 gallons (1-2 million gallons/year). Such a tannery would have only a few employees and probably not be representative. An average tannery might have 3-5 mills in operation.

Estimates of effluent volume for various production volumes are given in Table B.1.10. The major conclusion drawn from this data is that the waste water volumes tend to be very large and thus require some form of pretreatment prior to shipment to a processor.

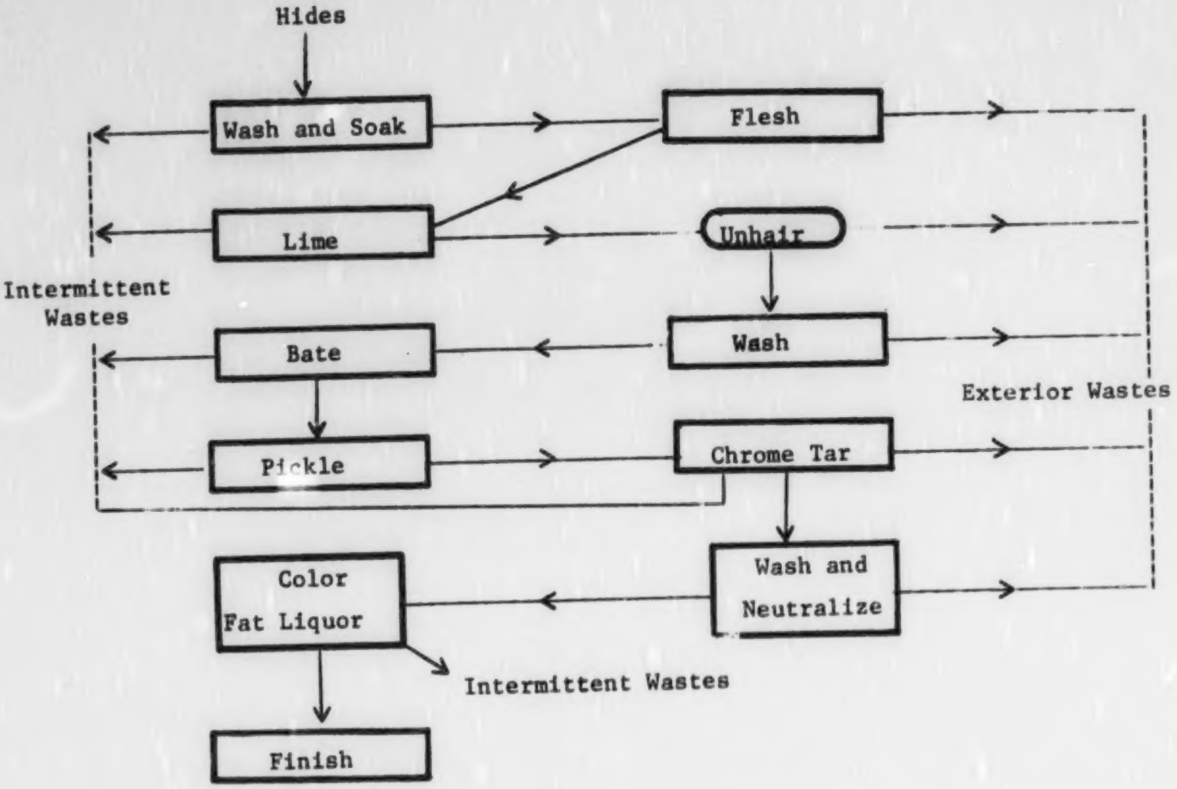
Hides
Wash and Soak
Flesh
Lime
Unhair
Intermittent Wastes
Bate
Wash
Exterior Wastes
Pickle
Chrome Tar
Color
Fat Liquor
Wash and Neutralize
Intermittent Wastes
Finish

FIGURE B.1.1

The Chrome Tanning Process

TABLE B.1.10

Tannery Wastes

No. of Mills	Hides Tanned per Day* (10^3 pounds)	Yearly Waste water Volume (10^6 gallons): With Chromium Segregated†	Yearly Waste water Volume (10^6 gallons): Total‡	Yearly Chromium Waste: Amount§ (10^3 pounds)	Yearly Chromium Waste: Sludge¶ Volume Gallons x10^3
1	5	4.5	9	10	15
2	10	9	18	20	30
10	50	45	90	100	150
20	100	90	180	200	300

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* - ADL estimate.

† - ADL estimate based on 4500 gallons per 1000 lb of hides.

‡ - Based on 9,000 gal/1,000 lb hides and 200 eight-hour days.

§ - Based on 10 lb chromium effluent per 1,000 lb hides.

¶ - Assume 7.5 gallons sludge from 10,000 gallons effluent.

Assuming precipitation of the chromium prior to shipment, one can expect 5-20 pounds of chromium per 1,000 pounds of treated hides. Thus, as shown in Table B.1.6, sludge volumes probably will be less than 100,000 gallons per year except for very large tanneries.

There is some variation in the available data as to how much chromium will be found in the effluent per 1,000 pounds of hides processed. For example, in an industrial waste study of the leather tanning and finishing industry (Contract No. 68-01-0024, October, 1971, Water Quality Office), Stanley Associates collected data on the chrome effluent from a number of cattle hide, sheepskin, and pigskin tanneries. The total chromium output varied considerably from one plant to another, with a range of 1 to 67 pounds of total chromium in the waste stream per 1,000 pounds of hides processed. The average value was about 6 pounds/1,000 pounds green salted hides.

During a visit to a pigskin tannery employing about 100 people, we learned that at full capacity the tannery processed almost 65,000 pounds of pigskin each day. To accomplish this, it utilizes 2,250 pounds/day of chromium in the chrome tanning step. The effluent from the chrome tanning tank contains about one pound of chromium per 1,000 pounds processed hides.

Activated sludge treatment of chrome tannery wastes was studied by the A.C. Lawrence Leather Company for its South Paris, Maine, tannery (Grant No. WPRD 133-01-68, September, 1969). In conjunction with that work, chromium analyses of the total waste water discharge were made over a 48-hour period. The results are shown in Table B.1.11. The tannery employs about 220 people. The average chromium concentration in the waste water effluent is somewhat less than 2 pounds/1,000 gallons.

In cattle hide tanning, which accounts for 80 percent of the industry volume, total waste water flow averages 8,000-10,000 gallons/1,000 pounds of green salted hides processed. The chromium effluent averages 5-20 pounds/1,000 pounds of green salted hides or 0.5 – 2.5 pounds/1,000 gallons of waste water. If these three tanneries surveyed are representative of industry, roughly 500,000-600,000 pounds/day of green salted hides would be processed per 1,000 employees.

TABLE B.1.11

WASTE WATER DISCHARGE FROM THE A.C. LAWRENCE CHROME UPPER SIDE LEATHER TANNERY IN SOUTH PARIS, MAINE

Waste Water Flow (gals/day)	Green Salted Hides Processed (lb)	lb Cr/1,000 lb hide
911,000	90,000	21
958,000	121,500	15
934,000	105,750	17

Cadmium Wastes from Battery Manufacturers

Introduction. In the United States 10 nickel-cadmium battery manufacturers generate wastes containing cadmium. Two of these – both in New Jersey – fall within our primary area for field investigation. The waste water volumes for all 10 are less than a million gallons a year so shipment to a central processing facility might be feasible in each case. However, the cadmium tends to be present as suspended solids and recovery by centrifugation is readily achieved. Therefore, in view of the small number of plants and the strong likelihood that many will treat the waste themselves for economic reasons, these battery manufacturers are not expected to be a major factor in a National Treatment System.

This section describes briefly the manufacturing processes for the negative (cadmium) plates of nickel-cadmium batteries. It identifies those steps in the process in which cadmium losses occur and assesses the efficiency of recovery in normal practice. The difference is assumed to be the quantity to be treated in the waste water.

On the basis of informal discussions of the problem with manufacturers, we estimated the quantity of waste water as a function of production capacity. From this information we than assessed the annual effluent disposal requirements in the nickel-cadmium battery industry as a function of its locations in the United States.

Manufacturing Processes for Nickel-Cadmium Battery Plates. There are two types of nickel-cadmium battery plates, the sintered plate and the pocket plate. In the former, the active material, cadmium hydroxide or nickel hydroxide, is deposited chemically in a highly porous nickel sinter. In the pocket plate battery, the active material is packed mechanically into a perforated cylinder of nickel plated steel. The methods of manufacture are quite different and will be discussed separately.

The process for sintered plates is set out diagramatically in Figure B.1.2. Initially, the porous nickel sinter – in strip form or precut to plate size – is vacuum impregnated with a 2 molar solution of cadmium nitrate containing some nitric acid. The nitrate is then converted to the hydroxide either by drying followed by immersion in 40 percent potassium hydroxide at 80 C (SAFT process) or by immersion without drying but with simultaneous cathodization at 150 milliamps/cm^2 (Fleischer process). The impregnation and conversion steps are repeated up to five times to obtain the required amount of cadmium hydroxide. The plates are washed and dried between each cycle, and particularly after the final cycle where the objective is to remove all residual potassium hydroxide and cadmium nitrate. Carbonate ions formed from the hydroxide ions and nitrate ions are very detrimental to battery operation and this necessitates the thorough washing. It is also important to avoid contamination with calcium and magnesium ions; for this reason it is essential to use deionized water. This introduces an economic constraint on the quantity of wash water used.

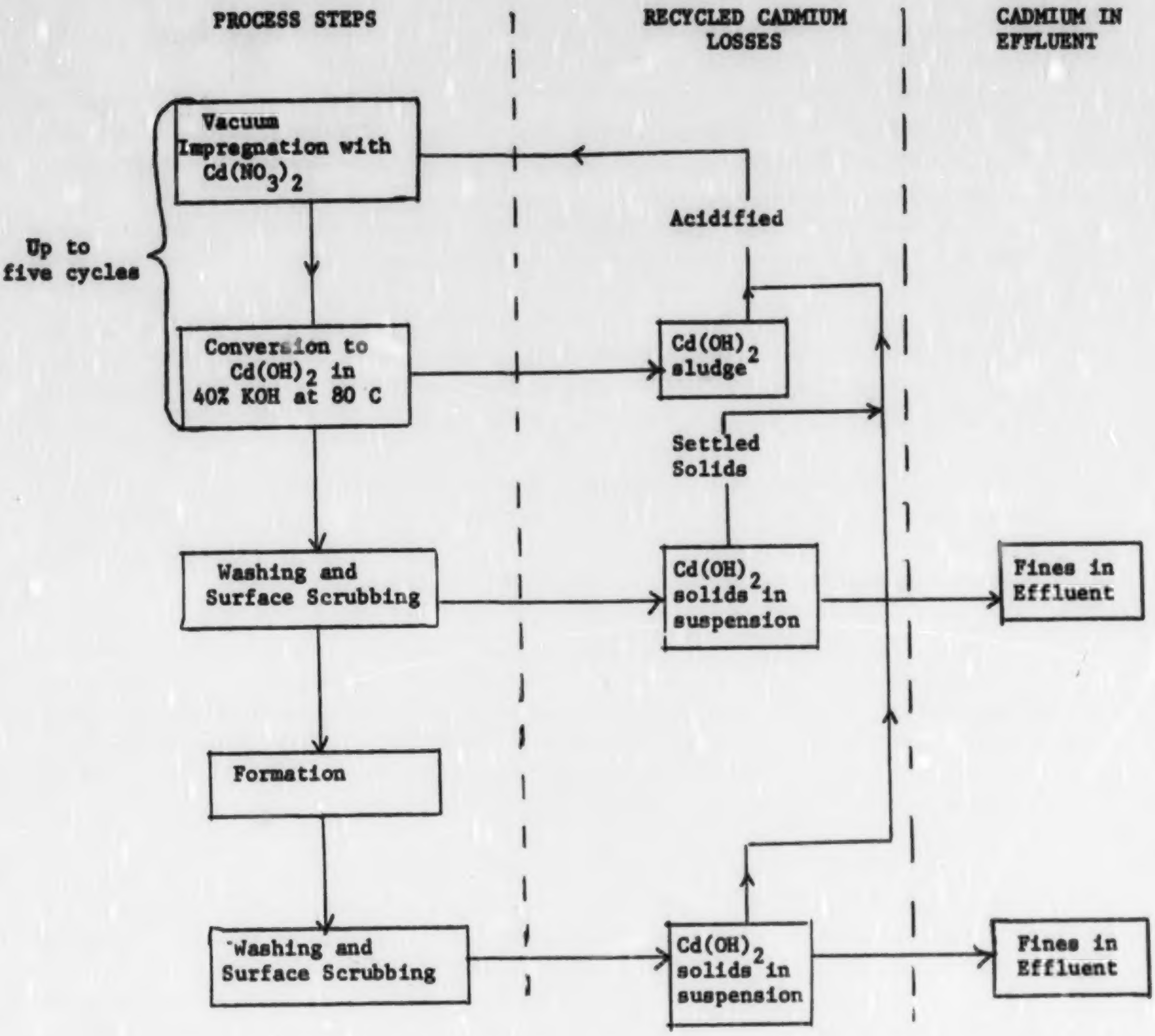
PROCESS STEPS
RECYCLED CADMIUM LOSSES
CADMIUM IN EFFLUENT
Vacuum Impregnation with Cd(NO3)2
Up to five cycles
Acidified
Conversion to Cd(OH)2 in 40% KOH at 80 C
Cd(OH)2 sludge
Settled Solids
Washing and Surface Scrubbing
Cd(OH)2 solids in suspension
Fines in Effluent
Formation
Washing and Surface Scrubbing
Cd(OH)2 solids in suspension
Fines in Effluent

FIGURE B.1.2

Manufacturing Process for Nickel-Cadmium Sintered Plates

The fully impregnated plates are scrubbed during the final wash process to remove loosely adherent cadmium hydroxide on the surface of the plate.

There are minor variations to these processes in which the cadmium nitrate or cadmium formate is partially decomposed thermally before immersion in potassium hydroxide. In this action cadmium vapor, particularly from the formate, is vented to the atmosphere.

Prior to assembly into cells the plates are exercised or formed in dummy battery packs. After formation these packs are disassembled and the negative plates again scrubbed and washed in deionized water.

The sources of cadmium losses, i.e., that quantity of cadmium that is introduced to the process but does not end up in a battery plate, are:

- The cadmium hydroxide sludge that forms because of precipitation outside the pore structure of the sinter in the potassium hydroxide conversion process;
- The wash water used during scrubbing after the impregnation process;
- The wash water used during scrubbing after the formation process; and
- The trim waste when plates cut from a continuous strip are trimmed to size.

These losses are estimated to amount to as much as 50 percent of the cadmium that ends up in the plates. The sludge would account for 35 percent of the loss and the scrubbings about 15 percent. It is difficult to assess the cadmium lost in trimming but this waste does not constitute liquid effluent and is easily disposed of.

Since cadmium is the most expensive component in the cell, every effort is made to recover as much as possible. This is relatively easy with the sludge which may be redissolved in nitric acid and added to the impregnation bath. There may be circumstances, such as accumulation of impurities or shutdown, when this recycling process is broken, but what remains is a solid waste disposal problem that is relatively straightforward because the cadmium hydroxide is highly insoluble. This high insolubility also insures that the soluble cadmium component in the effluent is less than 1-2 ppm; however, suspended solids (cadmium hydroxide) can dissolve quite readily in the presence of a complexing component such as ammonium ion or in a low pH environment.

The suspended solids in the wash water could account for losses of as much as 15 percent of the total cadmium utilized, and it is unlikely that this quantity would be reduced significantly by filtration or settling. Typically, for a plant capable of producing 10,000 ampere-hours of plate material per day, the wash water would carry off 4 pounds of cadmium per day as suspended cadmium hydroxide. This quantity is large enough to make centrifuging an economically attractive means of eliminating almost all the solids content, particularly since the volume of wash water is small, about 3,000 gallons/day. However, wash water is not treated routinely.

The processes for pocket plate manufacture are quite different from those for sintered plates. One involves the electrolytic coprecipitation of cadmium and iron sponge; the other involves the dry mixing of cadmium oxide or hydroxide with iron sponge in an edge runner mill. In the coprecipitation method, the active mix is washed extensively with water, which carries off some cadmium and iron sulfate. After the material is washed, it is pressed into cakes which are subsequently ground in a ball mill with a small quantity of paraffin to reduce the quantity of cadmium dust. The ground material eventually is packed into perforated steel envelopes to form the pocket plate. The plates are formed in a manner similar to that used for the sintered plates and are subsequently washed. The loss of cadmium hydroxide is significantly less in this case.

Though it has not been possible to obtain any firm figures for cadmium losses in pocket plate manufacture, it is an inherently cleaner process than sintered plate manufacture. The level of cadmium in the effluent from such a process is critically dependent on the cleanliness of the housekeeping operations. All soluble cadmium can be precipitated as the hydroxide if the wash water streams are treated and a very high percentage of the solids can then be removed, resulting in very low cadmium losses.

Location and Effluent Levels of Nickel-Cadmium Battery Manufacturers. Of the 10 battery producers, seven manufacture sintered plates. These 10 companies are located throughout the United States with one in Massachusetts, two in New Jersey, three in the Southeast, one in the Midwest, one in Texas and two in the Far West.

Our estimates for the volume of effluent from the sintered plate operation range from 40,000 to 900,000 gallons/year with an average of 450,000 gallons/year. Although the specific level is not known, the waste effluent from the three pocket plate manufacturers should be less than that for sintered plate. The cadmium losses are primarily as suspended solids since the solubility of cadmium hydroxide is less than 2 ppm at pH 8 and 25 C. The effluent will also contain potassium nitrate and potassium carbonate, possibly up to 1,000 ppm for each component.

As noted earlier, the quantities of effluent are small because of the requirement to use de-ionized water. With no treatment beyond a settling tank, it is estimated that the suspended solids could account for losses of up to 20 pounds/day of cadmium from the larger manufacturers. These losses can be virtually eliminated by the use of a centrifuge to collect the fines generated in the scrubbing process.

Other Sources of Waste Water Streams Containing Heavy Metals

In addition to those in the three categories discussed above, a number of industrial operations generate waste streams containing heavy metals of interest to this program. However, it is not likely that many of these will have a major impact on a Central Processing System. One exception is cooling towers where chromates are frequently used as a corrosion inhibitor.

Cooling Tower Blowdown Containing Chromates. Protection of the materials of construction in cooling towers and cooling systems requires the extensive use of corrosion inhibitors as well as the control of biological growths. Consequently, the water chemistry of a cooling tower depends upon the nature of the make-up water, the materials of construction of the system, and such operational characteristics as preventing heat transfer fouling from biological growths or chemical scale. In general, a cooling tower will concentrate the make-up water to one-third or one-fourth its original volume, but the concentration ratio depends upon the total dissolved solids concentration of the make-up water. That is, higher concentration ratios are possible with low total dissolved solids (TDS) make-up water and vice-versa.

The dissolved solids concentration is usually established by the scale formers such as the calcium salts, and since sulfuric acid is often added to cooling towers, calcium sulfate solubility most often determines the limits on total dissolved solids. Corrosion inhibiting chemicals such as chromates, phosphates, zinc, etc., are usually added to the circulating cooling waters in varying concentrations. Some cooling towers may maintain a concentration of over 200 ppm sodium chromate when this chemical is used as the only corrosion inhibitor. However, lower concentrations, such as 40-60 ppm, are often used in conjunction with polyphosphates. Chemicals for the control of bacterial growths, either biocidal or biostatic, are also included in cooling tower and cooling system designs. Consequently, the composition of the circulating cooling water is usually a complex mixture of chemicals from the make-up water and those added to control conditions unique to the system.

Cooling water is emitted into the environment from two sources: the "drift" or mechanical loss of water droplets that are carried out by the air passing through the tower, and the "blowdown" or bleed stream necessary to control the concentration of total dissolved solids within a satisfactory operating range. Although drift losses may cause a considerable build-up of cooling tower chemicals in the ground around a cooling tower, the major concern in this study is for the disposal of the cooling tower blowdown.

The magnitude of cooling tower blowdown depends upon a number of parameters such as drift loss, the temperature difference across the cooling tower, and the chemical composition of the make-up and circulating water. Present day industrial cooling towers are guaranteed to have a drift loss of less than 0.2 percent of the circulating water; that is, if the circulation rate is 1,000 gallons/minute (gpm) the drift loss will be less than 2 gallons/minute. Since the drift rate is not highly dependent upon the temperature differences across the cooling towers, it is possible for a cooling tower with a high drift rate and a low temperature difference, i.e., 1 to 10 F, to require no blowdown; the drift rate will keep build-up in concentration of TDS within an acceptable range.

As a general "rule of thumb," the blowdown from a cooling tower will approximate 0.3 percent of the circulation rate for each 10 F difference between incoming (hot) and outgoing (cold) water. That is, for a cooling tower operating with incoming water at 110 F and outgoing water at 90 F the blowdown would be approximately 0.6 percent of the circulation rate. Since approximately 1 percent of the circulated water must evaporate for each 10 F difference, a 0.3 percent blowdown would allow the total dissolved solids concentration in the make-up water to increase by a factor of 3 1/3 if no drift losses occurred and no conditioning chemicals were added. If a drift loss of 0.2 percent occurred, the concentration ratio would be 2 for the same 0.3 percent blowdown.

To provide another perspective to the magnitude of the cooling tower blowdown problem, assume a cooling tower handling a 100-ton refrigeration system such as might be installed on an office building. This cooling tower will probably require the circulation of about 300 gallons/minute of water with a 10 F temperature difference, i.e., a rejection of 1.5×10^6 Btu/hr to the atmosphere* via evaporation with a blowdown of approximately 1300 gallons/day or another 50,000 gallons/month. The removal of toxic or hazardous polluting substances from these blowdown streams before disposal into receiving waters will obviously depend upon specific local conditions and the size of the blowdown stream. For large industrial cooling towers, the use of chromate corrosion inhibitors – probably the most effective inhibitor – may be continued and the blowdown treated on-site for removal of chromium and disposal as a sludge.

In the case of small commercial cooling tower installations, it may be most expedient to change to a different, less hazardous, but less effective system of corrosion inhibitors.

Smelting and Refining. Another source of wastes that contain heavy metals of interest to this program is the smelting and refining industry. Because of the nature of this industry, however, it is not likely to have a major impact on a Central Processing System except in a few geographical regions. For example, almost all of the direct refining of arsenic ores or oxide powders is done by the American Smelting and Refining Company (ASARCO) in the State of Washington. Thus, there really is only a local area where arsenic wastes from the refining of arsenic ores would be possible.

Arsenic is an impurity in most copper ores, so in the production of copper metal it is generated as one component in the waste product. However, the arsenic is generated mostly as particulate, which is collected and sent to ASARCO for treatment. Aqueous wastes containing arsenic also come out in the copper refining process at several points, but this waste is also sent to ASARCO. Therefore, arsenic wastes from mining and smelting really are a potential problem only to the Northwest.

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*The difference between the 1.2×10^6 Btu/hr for the 100 tons of refrigeration and the 1.5×10^6 Btu/hr rejected arises from the inefficiencies of the refrigeration system.

Antimony plants are either in Texas or in the Northwest; thus the direct refining of antimony is also a very regional and localized problem. However, there are a number of secondary smelters for lead in which antimony is a by-product, and these plants probably can be found throughout the country. Mostly, these smelters utilize recycled material, such as batteries, and the waste comes from sludge or water effluent containing heavy metals. Most of the secondary smelters are relatively small, so waste streams would not be large, although there are a few big ones, with National Lead Industries being the biggest.

Cadmium is found with zinc ores, so cadmium-containing wastes are generated when zinc is mined and refined. Because these operations are large, however, the waste streams would be extremely large and any treatment necessary would be done on-site. There are some zinc smelters scattered around the country, but not too many – a few in western Pennsylvania, a few in St. Louis, one in Corpus Christi, one in Idaho, and possibly a few others; but by and large, because of the relatively small number of these, the impact on a Central Processing System would be minimal.

Mercury is extracted by a dry process through volatilization and thus would not lead to much aqueous or solid waste. Once again, this problem is localized in the West. There are other places where mercury could be a problem, e.g., chlor-alkali plants and the mercury emissions from power plants that burn coal. Water streams of the former already are being treated, so at most, only sludges would show up in a National Treatment System. If the mercury vapors from coal burning are collected by oxidative aqueous scrubbing (which is a likely route) then the influence on a National Treatment System would come from the treated sludge. This problem may have to be faced by power plants in the future, but does not exist at present.

All of the chromium ores are imported, and go into making iron and steel, electrolytic chrome, or chromate chemicals. In iron and steel the wastes would be of large volume so that on-site processing probably would be preferred. However, it is likely that frequently the sludge would be sent to a Central Processing Center. Chromate chemicals are produced in only a few plants so this would not be a major issue. Electroplating wastes are covered in another section.

Mercury. Outside of mercury metal production, which has little waste, the primary sources of mercury waste material are chlor-alkali plants, paint manufacture and production of organic chemicals such as pesticides. Pesticides and paints have been discussed earlier in this appendix.

Based on information supplied by TRW, it would appear that brine sludges from chlor-alkali plants very likely will be candidates for shipment to central processing plants.

Common practice now is to treat the original waste water stream with precipitating agents to form a salt sludge which contains small quantities (100 ppm) of mercury that has been carried along with the precipitate.

Total quantities of brine sludge range from practically none to about 1.3 million gallons. In almost all cases, therefore, it is likely that on an economic basis, these sludges would be shipped to a regional (local) processing facility. Although there are 29 installations in the United States, only one is located in our primary field area (Pennsylvania-New Jersey). Because of the few locations these wastes will not likely have a major influence on a regional waste treatment facility.

APPENDIX B.2

IDENTIFICATION OF SPECIFIC SOURCES

Tables B.2A-B.2H provide details for known waste sources within the Northeast and Middle Atlantic States. The data in these tables were obtained through telephone calls and personal visits by ADL personnel, as well as from information from companies treating industrial wastes. The categories covered are:

Table No.	Category
B.2.A	Concentrated Heavy Metals
B.2.B	Dilute Heavy Metals
B.2.C	Dilute Heavy Metals with Organics
B.2.D	Heavy Metal Sludges
B.2.E	Concentrated Cyanides
B.2.F	Dilute Cyanides with Heavy Metals
B.2.G	Liquid Wastes with Chlorinated Hydrocarbons
B.2.H	Organic Wastes Requiring a Rotary Kiln

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TABLE B.2.A

CONCENTRATED HEAVY METALS

Waste Code	Waste Description Form	Hazardous Material	Other	Waste Volume (gallons/yr)
A-1	Liquid	0.5% arsenic	NaCl, Na_2SO_4	500,000
A-2	Liquid	0.1-0.3% arsenic, 0.4% selenium	4% HCl, 7% H_2SO_4, 150 ppm copper	940,000
A-3	Liquid	3-5% arsenites and arsenates (1/3 organic)	trace aniline and organics with arsenic	600,000
A-4	Liquid	1% cadmium amino complex	2-3% other metals, 0.5-1% NH_4OH	180,000
A-5	Liquid with solids	85 ppb mercury	10-15% HCl, metal chips, hydrocarbons	50,000
A-6	Solution	8.5% chromic acid	20% H_2SO_4, trace lead, iron	66,000
A-7	Solution	11% chromic acid	14% H_2SO_4, 800 ppm copper	45,000
A-8	Water slurry	2.5% chromium	33% Al_2O_3, filter aid	250,000 lb (drums)
A-9	Solution	5-14% chromic acid	10-30% H_2SO_4	520,000 (drums)
A-10	Sludge	5-50% chromic oxide	organics, filters, etc.	70,000 lb (drums)

TABLE B.2.B

DILUTE HEAVY METALS

Waste Code	Waste Description			Waste Volume (gallons/yr)
	Form	Hazardous Material	Other	
B-1	Liquid	0.05-0.1% arsenic acid	5% HCl, 5% H_2SO_4, traces of other metals	260,000
B-2	Liquid	chromate from plating rinse		8,640,000
B-3	Liquid	22 ppb mercury, 60 ppm chromium	1% HF, 7% HNO_3, 400 ppm copper	60,000
B-4	Liquid	5 ppm mercury	25,000 ppm copper, 15-30% ammonium persulfate	3,000 (drums)
B-5	Liquid	heavy metals, including chromium		600,000
B-6	Liquid	electroplating waste stream with chromate		5,000,000
B-7	Liquid	2000-3000 ppm chromium	20% aluminum sulfate, 25% sulfuric acid	420,000
B-8	Liquid	1000-5000 ppm chromium	1500 ppm other metals, 15% mixed acids	3,600,000
B-9	Liquid	ppm of chromium, cadmium, copper, etc.		1,500,000
B-10	Liquid	5000-7000 ppm chromate	sodium sulfate, trace of hydrocarbons	75,000

TABLE B.2.B (Continued)

DILUTE HEAVY METALS

Waste Code	Waste Description Form	 Hazardous Material	 Other	Waste Volume (gallons/yr)
B-11	Liquid	120-180 ppm chromate	200 ppm aluminum, pH-3	2,500,000
B-12	Liquid	ppm of nickel, copper, cadmium chromium		10,000,000
B-13	Liquid	metal plating rinse bath		60,000,000
B-14	Liquid	120 ppm chromium	0.25% other metals, 15% acid	200,000

TABLE B.2.C

DILUTE HEAVY METALS WITH ORGANICS

Waste Code	Waste Description				Waste Volume (gallons/yr)
	Form	Hazardous Material	Other		
			Inorganic	Organic	
C-1	Liquid	2-5 ppm arsenic	pH 9-11	4000-12,000 ppm BOD	1,500,000
C-2	Liquid with Solids	300-500 ppm cadmium	2-3% aluminum	organic cleaners	145,000
C-3	Liquid	200 ppm mercury	---	2-3% bactericide, oils	25,000
C-4	Liquid	15 ppb mercury	---	alkaline metal cleaner	96,000
C-5	Liquid	chromium	waste from tanning		100,000,000
C-6	Liquid	32 ppb mercury	alkaline	COD 30-120,000 ppm	300,000
C-7	Liquid	250-750 ppm chromate	SiH, traces of metals	1-2% organics	520,000
C-8	Liquid	2000-4000 ppm chromate	---	1% organic cleaners	480,000
C-9	Liquid	100 ppm chromium	400-900 ppm Cu	200-400 ppm phenol, 1% coal tar dye	3,500,000
C-10	Liquid	chromium	waste from tanning		100,000,000
C-11	Liquid	dichromate	1-2% Cu	1% oils, soaps	100,000

TABLE B.2.D

HEAVY METAL SLUDGES

Waste Code	Waste Description Form	Hazardous Material	Other	Waste Volume (gallons/yr)
D-1	Wet Cake	8% arsenic sulfide	phosphates, filter aid	750,000 lb (drums)
D-2	Water Slurry	8% arsenic sulfide	phosphoric acid, carbon	42,000 lb (drums)
D-3	Water Slurry	2% arsenic oxide	filter aid, 100-500 ppm chlorinated hydrocarbons	30,000 gal.
D-4	Water Slurry	2% arsenic sulfide	7% carbon, 5% H_3PO_4, 20% filter aid	50,000 lb (drums)
D-5	Water Slurry	8% arsenic compounds	13% filter aid	200,000 lb
D-6	Slurry	cadmium carbonate/hydroxide	nickel carbonate, other metal carbonates and hydroxides	500,000 gal.
D-7	Slurry	125 ppm cadmium, 275 ppm chromium	2% copper hydroxide, 25% filter aid	1,150,000 lb
D-8	Sludge	600 ppb mercury	20% $Ca_3(PO_4)_2$ and metal hydroxides, 5% filter aid	130,000 gal.
D-9	Sludge	75-400 ppm chromium hydroxide	$CaSO_4$, CaF_2, 4000 ppm iron hydroxide	3,500,000 gal.

TABLE B.2.E

CONCENTRATED CYANIDES

Waste Code	Waste Description: Form	Waste Description: Hazardous Material	Waste Description: Other	Waste Volume (gallons/yr)
E-1	Liquid	7% sodium cyanide	2% NaOH, dilute silver	310,000
E-2	Liquid	8.5% sodium cyanide, 4% metal cyanide (CaZn)	alkaline	18,000
E-3	Sludge	1,000 ppm cyanide, 0.3% chromium	nickel, zinc	60,000
E-4	Liquid	0.4% cyanide, 14.5% sodium thiocyanate	sulfides, thiosulfate	700,000
E-5	Liquid	1% potassium ferrocyanide	10% NaOH, 1,000 ppm sulfide	15,000 (drums)
E-6	Liquid	0.75% cyanide, 0.65% Cu, 0.2% chromium	8% NaOH	15,000 (drums)
E-7	Liquid	0.4% cyanide	0.2% iron, 2% NaOH	50,000
E-8	Liquid	sodium cyanide	acrylonitrile	45,000 (drums
E-9	Water/oil mixture	2-3% sodium cyanide	30% oil	6,000 (drums)
E-10	Slurry	75 ppm cyanide, trace copper, zinc	45% solids	7,500 (drums)
E-11	Liquid	3% sodium cyanide with zinc	trace hydrocarbon	260,000
E-12	Liquid	8% copper cyanide	1-2% NaOH, 250 ppm Ni, Zn	25,000

TABLE B.2.F

DILUTE CYANIDES WITH HEAVY METALS

Waste Code	Waste Description			Waste Volume (gallons/yr)
	Form	Hazardous Material	Other	
F-1	Liquid	0-50 ppm cyanide	0.5-1.5 sodium cyanate, 0-50 ppm NaOCl	120,000
F-2	Liquid	cadmium cyanide	sodium hydroxide	8,000
F-3	Liquid	electroplating waste stream		1,000,000
F-4	Liquid	30-60 ppm cyanide	1-1.5% trichloroethylene	46,000
F-5	Liquid	25-40 ppm cyanide	200 ppm iron, 800 ppm phenol alkaline, high COD	210,000
F-6	Liquid	7000 ppm copper cyanide	trace amines (plating rinse)	200,000
F-7	Liquid	150 ppm cyanide	7% phenol, 15% NaOH	60,000

TABLE B.2.G

LIQUID WASTES WITH CHLORINATED HYDROCARBONS

Waste Code	Waste Description			Waste Volume (gallons/yr)
	Form	Hazardous Material	Other	
G-1	Liquid	30% DDT, 10% trichloroethylene	60% solvent	20,000 (drums)
G-2	Liquid	15% organothiophosphates	65% alcohol, 15% H_2O	25,000
G-3	Liquid	10% parathion/malathion	10% xylene	20,000
G-4	Liquid	25% trichloroethylene	65% other organics	125,000
G-5	Liquid	5% perchloroethylene	Remainder solvents	100,000
G-6	Liquid	45% carbon tetrachloride	55% sulfur monochloride	50,000
G-7	Liquid	30% halogenated organics	5% water, 65% polycyclics	40,000
G-8	Liquid	10% methylene chloride	15% water, remainder other solvents	500,000
G-9	Liquid	40% epichlorohydrin, 20% trichloropropanols	40% mixed solvents	90,000
G-10	Liquid	30% chlorinated solvents	70% alcohols, ketones	160,000 (drums)
G-11	Liquid	95% nitrochlorobenzenes	---	500,000
G-12	Liquid	5% chlorobenzene	toluene, 15% water	100,000
G-13	Liquid	70% chlorobenzenes	30% tors	670,000
G-14	Liquid	85% PCB	kerosene	40,000
G-15	Liquid	40% PCB	20% xylene, bal. water	10,000

TABLE B.2.G (Continued)

LIQUID WASTES WITH CHLORINATED HYDROCARBONS

Waste Code	Waste Description			Waste Volume (gallons/yr)
	Form	Hazardous Material	Other	
G-16	Liquid	chloroethylenes	---	155,000
G-17	Liquid	chlorobenzene	sodium hydroxide	190,000
G-18	Liquid	chloroethylene	chlorocyclics	240,000
G-19	Liquid	chlorotoluenes	---	420,000
G-20	Liquid	trichloroethylene	spent solvents	20,000
G-21	Liquid	25% phosphorothioates	15% alcohol, 5% sodium sulfate	100,000
G-22	Liquid	20% organophosphates	10-15% phenates	1,000,000 lb
G-23	Liquid	herbicide tars, including 2,4-D	glycols, ether	110,000 (drums)
G-24	Emulsion	13% perchloroethylene	10% sodium oxalate in water	45,000
G-25	Aqueous slurry	14% epichlorohydrin	60% organics, 15% sodium hydroxide	42,000
G-26	Viscous liquid	75% dichlorobenzenes	25% tarry residue	200,000

TABLE B.2.H

ORGANIC WASTES REQUIRING A ROTARY KILN

Waste Code	Waste Description Form	 Hazardous Material	 Other	Annual Waste Volume
H-1	Slurry	antimony chlorides	2% HCl, HF, metals, 52% tetrachloroethane	7,000 lb
H-2	Sludge	antimony oxides	water, hydrocarbons	10^6 lb
H-3	Solid Waste	50-3000 ppm arsenic powder 20-5,000 ppm selenium	filters, rags, gloves, cartridges, etc.	55,000 lb (drums)
H-4	Slurry	0.5-1% cadmium phosphate	45% alcohols, mineral spirits	36,000 gal
H-5	Sludge	0.5-1% mercury	metal hydroxides; organics	20,000 gal (drums)
H-6	Solid	40 mg mercury/unit	carbon, plastic, MnO_2, Zn	1-2 x 10^6 units
H-7	Water Slurry	2.5% heptachlor	10% diatomaceous earth	50,000 gal.
H-8	Water Slurry	5-8% parathion/malathion	5-10% diatomaceous earth	25,000 gal.
H-9	Water	30% phosphorothioates	3% filter aid, 5% Na_2SO_4	40,000 gal.
H-10	Sludge	100 ppm tetraethyl lead	gasoline storage tank sludge	20,000 gal.
H-11	Sludge	400 ppm tetramethyl lead	gasoline storage tank sludge	1,000,000 gal.
H-12	Slurry	80-95% trichloroethylene	5-20% water, oil, solids	72,000 gal.
H-13	Aqueous Solution with Solids	7% trichloroethylene	10% oil, metal chips	50,000 gal.

TABLE B.2.H (Continued)

ORGANIC WASTES REQUIRING A ROTARY KILN

Waste Code	Waste Description			Annual Waste Volume
	Form	Hazardous Material	Other	
H-14	Trash	10% ethylene dichloride	10% solvents, 10% water on trash	200,000 gal.
H-15	Aqueous Slurry	2-20% ethylene dichloride	20% methanol, 10% methylal	1,000,000 gal.
H-16	Slurry	10% trichloroethylene	40% polymer, oils	240,000 lb (drums)
H-17	Slurry/Sludge	40% nitrochlorobenzene	25% water, nitrotoluene	600,000 gal.
H-18	Slurry	65% chlorotoluenes	5% inorganic salts, water, alcohols	100,000 gal (drums)
H-19	Solid Waste	8% PCB soaked on rags		1,200 55-gal drums
H-20	Viscous Slurry	70% chlorobenzenes	aromatics	680,000 gal.
H-21	Semi-Solid	chloroaromatics	xylene	170,000 gal.

APPENDIX C

PROCESS ECONOMICS

BACKGROUND

This appendix summarizes our estimates of capital and operating costs for the major components of each process included in Figure 3.1. The common cost factors on which these estimates are based are summarized in Table 3.3. For the convenience of the reader we have presented our description in terms of the same eight categories of chemical types used in Appendix B:

1. Concentrated heavy metals
2. Dilute heavy metals
3. Heavy metals with organics
4. Heavy metal sludges
5. Concentrated cyanides
6. Dilute cyanides with heavy metals
7. Liquid waste with chlorinated hydrocarbons
8. Organic wastes requiring rotary kiln.

For comparative purposes, we have also included summary cost tables of some of the less attractive processes, and the cost for evaporation versus shipment distance and cost. Finally, we have included the economics of using a portable unit to destroy insecticide containers.

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CONCENTRATED HEAVY METALS

The type of treatment used for heavy metal wastewater will depend on the species of heavy metal present, their form (e.g., soluble or slurry; sulfide or hydroxide) and their concentration.

As shown in Figure C.1, the volume of the free settled, filtered or centrifuged sludge (hydroxide or sulfide) can approach or even exceed the volume of the wastewater solution in which the soluble metal salt occurs and thus presents a problem in ultimate disposal. If it were necessary to transport the final sludge any distance for ultimate disposal, the volume of this sludge in relation to the original volume of the wastewater would have to be considered in the economics.

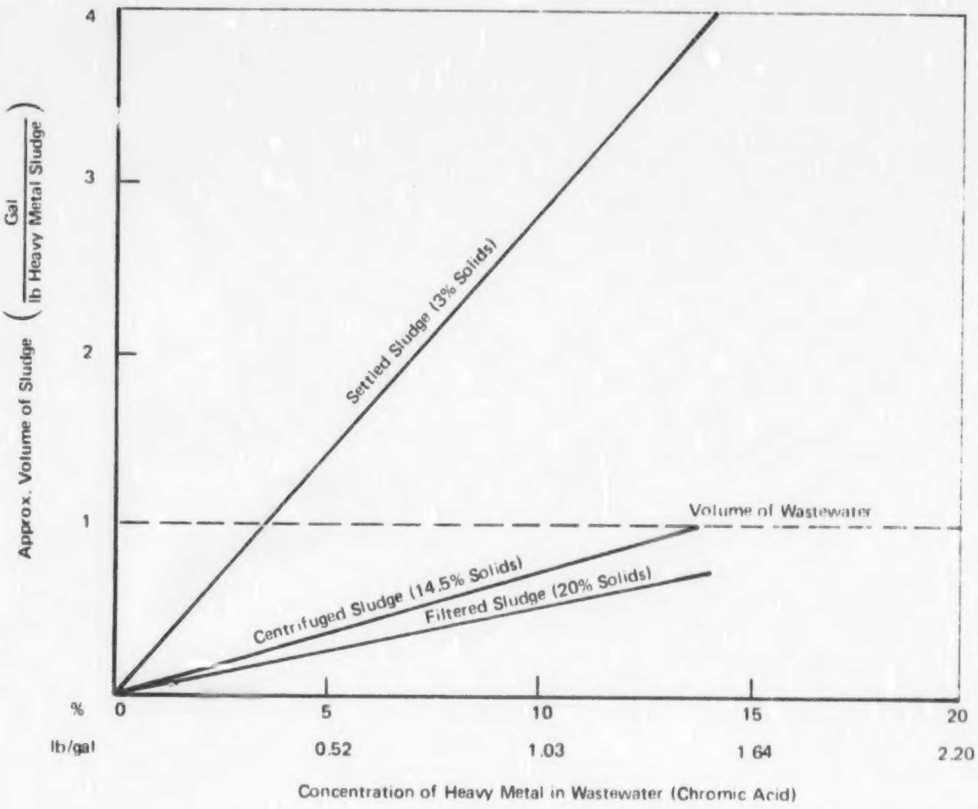


FIGURE C.1 COMPARISON OF HEAVY METAL SLUDGE VOLUME WITH VOLUME OF WASTEWATER

For our first example (Figure C.2 and Table C.1), we have taken the following concentrated heavy metal waste:

100,000 ppm CrO_3 in 20% H_2SO_4
10,000 gal/week (2000 gal/day)

TABLE C.1

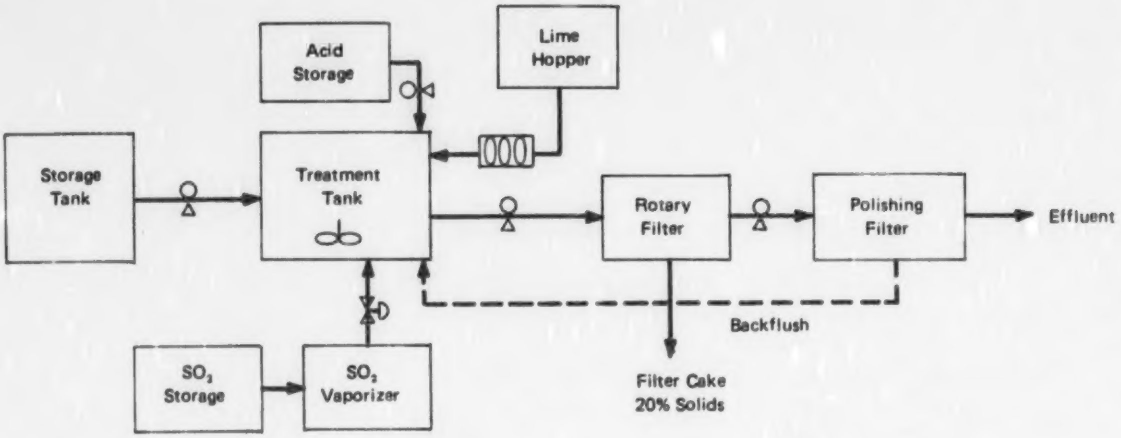
TREATMENT COST OF CONCENTRATED CHROME WASTEWATER

Basis: 2000 gal/day 100,000 ppm CrO_3

				$/day
Chemicals				
	SO_2	240 lb/day	@ 10¢/lb	24
	Lime	2000 lb/day	@ $20/ton	20
Utilities				
	Pumps, Conveyor		20 HP	2
	Agitator		5 HP	
			25 HP x 8 = 200 HP hrs	
Labor				
	2 men x 8 hrs/day x $5.50/man-hr			88
	Overhead @ 50% Labor			44
Depreciation		20% FCI/yr	$34,000/yr	142
Maintenance		5% FCI/yr	8,500/yr	35
Insurance & Taxes		2% FCI/yr	3,400/yr	14
				$369/day
				$0.18/gal

Dewatered Sludge Output 115 ft^3/day

The conventional industrial treatment for a concentrated chrome wastewater is reduction by SO_2 and precipitation by lime. (This method was suggested for an NDS by TRW.) $FeSO_4$ also may be used as a reducing agent, but it produces a more voluminous sludge. Proper disposal of the hydroxide sludge generated is an additional cost in these processes. (Refer to Table C.9.)



Acid Storage
Lime Hopper
Storage Tank
Treatment Tank
Rotary Filter
Polishing Filter
Effluent
Backflush
Filter Cake 20% Solids
SO_2 Storage
SO_2 Vaporizer

Waste Storage	\$ 6,000
Treatment Tank	6,500
SO_2 Storage (1-Ton-Tank Rental)	---
SO_2 Vaporization System	2,000
Acid Storage	600
Lime Hopper and Feed Conveyor	7,000
Rotary Vacuum Filter	25,000
Polishing Filter	5,000
Pumps	2,500
Instruments (Redox, pH) and Recorders	2,500
Purchased Equipment	\$ 57,100 x3
Total Fixed Capital Investment	\$171,300
Round to	\$170,000

Basis: 2000 gal/day Chrome Wastewater Batch Treatment
100,000 ppm CrO_3 (85% as Cr^{+3}), SO_2 Reduction
20% H_2SO_4 240 days/yr 1 shift/day

FIGURE C.2 TREATMENT OF CONCENTRATED CHROME WASTEWATER

DILUTE HEAVY METALS

For the second example we have compared treatment of a dilute chrome wastewater by ion exchange (Figure C.3 and Table C.2), or by SO_2 reduction to Cr^{+3} and precipitation by lime as the hydroxide (Figure C.4 and Table C.3). In the ion exchange process, the rinse waters flow through the cation exchange, which removes metals other than chrome, 1,* and into the anion exchanger, which removes chromate ion and yields demineralized water, 2. The chromate ion is stripped from the anion exchanger with caustic, which produces sodium dichromate, 3, and chromic acid is produced, 4, as the sodium ion is stripped from the sodium dichromate in the cation exchanger. Both of these methods are used industrially for the treatment of dilute chrome wastewater.

TABLE C.2

RECOVERY OF CHROMIUM FROM DILUTE WASTEWATER BY ION EXCHANGE

Basis: 10,000 gal/day 130 ppm Cr^{+6} 200 ppm Al^{+3}

			$/day	(Rounded) $/day
Chemicals				
NaOH	26 lb/day	0.04	1.04	13.00
H_2SO_4	372 lb/day	0.01	3.72	
CaO	160 lb/day	0.01	1.60	
Exch. Resin	0.3%/day	$36ft^3$ x $\$60/ft^3$	6.48	
Utilities			1.00	1.00
Labor	4 man-hrs x $5.50/man-hr		22.00	22.00
Overhead	@ 50% Labor		11.00	11.00
Depreciation	20% FCI/yr	$13,600/yr	57.00	57.00
Maintenance	5% FCI/yr	3,400/yr	14.00	14.00
Taxes & Insurance	2% FCI/yr	1,400/yr	6.00	6.00

$124/day

Credits Water $(10{,}000 \times \frac{\$0.40}{1000})$ = $4/day

Chromic Acid (21 x $0.30) = $6/day

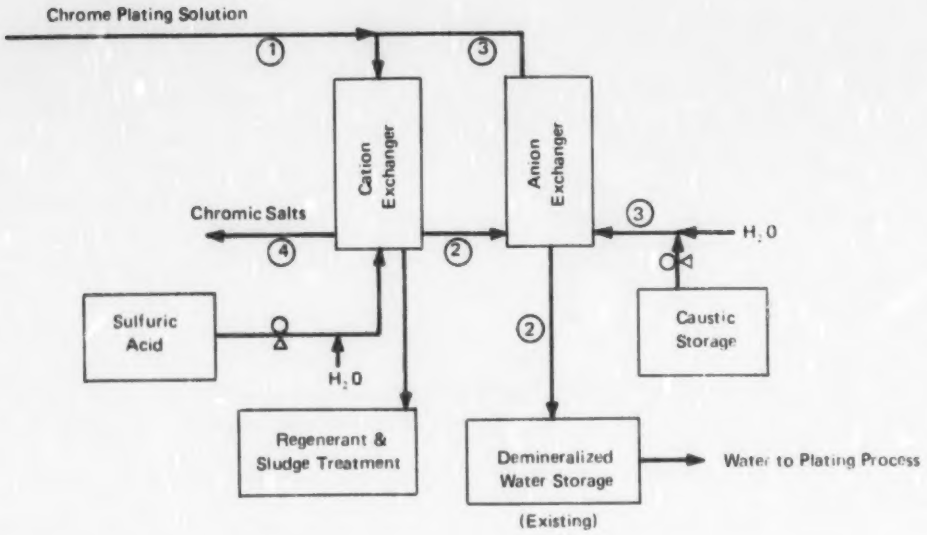
Net $114/day

$0.011/gal

Sludge Output $30ft^3$/day
(Mainly Calcium Sulfate from H_2SO_4 neutral.)

---

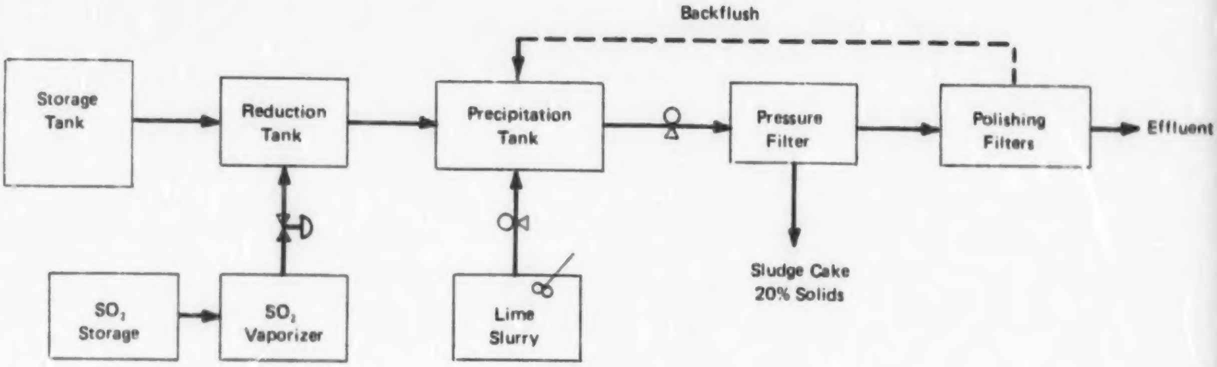
* Numbers refer to process steps shown in Figure C.3.


Chrome Plating Solution
①
③
Cation Exchanger
Anion Exchanger
Chromic Salts
④
②
③
H_2O
Sulfuric Acid
H_2O
②
Caustic Storage
Regenerant & Sludge Treatment
Demineralized Water Storage
(Existing)
Water to Plating Process

Cation Exchange Unit with Automatic Controls	$11,000	
Anion Exchange Unit with Automatic Controls	6,500	
Acid Storage	1,000	
Caustic Storage	400	
Pumps, In-Line Mixers, Flowmeters	2,500	
Regenerant/Sludge Treatment System	6,000	
Purchased Equipment	$27,400	
	x2.5	(Exchange Units Complete with Controls)
Fixed Capital Investment	$68,500	
Round to	$68,000	

Basis: 10,000 gal/day
130 ppm Cr^{+6}
200 ppm $A\ell$
240 days/yr Operation
Continuous Operation

FIGURE C.3 RECOVERY OF CHROMIUM FROM DILUTE WASTEWATER BY ION EXCHANGE


Backflush
Storage Tank
Reduction Tank
Precipitation Tank
Pressure Filter
Polishing Filters
Effluent
Sludge Cake 20% Solids
SO_2 Storage
SO_2 Vaporizer
Lime Slurry

Waste Storage	\$11,200
Reduction Tank	5,000
SO_2 Vaporizer & Controls	1,500
Lime Slurry Tank	2,000
Pressure Filter Plate & Frame	5,500
Polishing Filters	500
Purchased Equipment Cost	\$18,300
	x3
Fixed Capital Investment	\$54,900
Round to	\$55,000

Basis: 10,000 gal/day Continuous Treatment
130 ppm Cr^{+6}
200 ppm $A\ell^{+3}$

FIGURE C.4 TREATMENT OF DILUTE CHROME WASTEWATER (Reduction & Precipitation)

TABLE C.3

TREATMENT COST OF DILUTE CHROME WASTEWATER

Basis: 10,000 gal/day 240 days/yr operation
130 ppm Cr^{+6}
200 ppm Al^{+3}

Chemicals					$/day
	SO_2	22 lb/day	@ 10¢/lb	$2.20	3.00
	Lime	56 lb/day	@ 1¢/lb	0.56	
Utilities	(Power)				1.00
Labor	4-man-hrs/day x $5.50/man-hr				22.00
Overhead					11.00
Depreciation		20% FCI/yr	$11,000/yr		46.00
Maintenance		5% FCI/yr	2,800/yr		11.00
Taxes & Insurance		2% FCI/yr	1,100/yr		5.00
					$99.00/day
					$0.0099/gal
					$0.01/gal

Sludge Output 1ft^3/day

A typical waste stream of this type would have the following composition:

Flow: 10,000 gallons/day
130 ppm Cr^{+6}
200 ppm Al^{+3}

As shown in Figures C.3 and C.4 the net cost of either means of treatment would be nearly the same.

We also considered a portable ion exchange unit. Such a unit could be built much larger because it would treat waste from, say, three or four sites one week per month at each site. There would be a savings because of the size factor. Quadrupling the size, would increase the cost only 2.3 times and each site would have to pay for one-fourth of the unit's time. Other savings might be possible because the unit might not have to be housed. However, we assumed that the cost of modifying a trailer truck would be equivalent to the cost of building housing for the stationary ion exchange unit. Furthermore, in mild climates the stationary unit would be outdoors anyway.

Cursory calculations (see Table C.4) show that a portable unit would be marginal. To calculate the depreciation on the truck and trailer, we assumed that one truck would service four trailers and that each trailer would house an ion exchange unit sufficient to process 200,000 gallons of liquor in one 5-day week. For our example of 10,000 gallons per day of wastewater, the trailer would be used one week per month operating on a 200,000 gallon pond. We have also assumed a 5-year depreciation rate on the trailer and tractor. The user

TABLE C.4

ECONOMIC COMPARISONS PORTABLE VS STATIONARY ION EXCHANGE

	Portable ($)	Permanent ($)
Capital Investment		
Pond	$30,000	–
Truck & Trailer	[35,000] *	
Ion Exchange Equipment	[156,000] *	68,000
	$/Year	**$/Year**
Operating Costs		
Chemicals	Unchanged	
Labor	Unchanged	
Overhead	Unchanged	
Depreciation prorated including 70% utilization efficiency		
Equipment	11,200	13,600
Truck & Trailer	2,500	–
Pond	3,000	–
	$16,700	$13,600
Depreciation prorated assuming 100% utilization efficiency		
Equipment	7,800	13,600
Truck & Trailer	1,750	
Pond	3,000	
	$12,550	$13,600
Savings	$ 1,000	

*Trailer and ion exchange equipment occupancy requirements for this project, 25%

*Tractor occupancy requirement for this project 25% x 25% = 6%.

would not have to invest in ion exchange equipment – a savings of $68,000. However, he would have to have sufficient land to build a retention pond to save his waste for a month. Such a pond, to be absolutely safe, should be lined. Thus we calculate its cost at $30,000.

Table C.4 does not differentiate ownership between the portable and the permanent system because the charge for its use would have to be sufficient to cover depreciation of equipment as well as operating cost. One finds that the depreciation on the pond and trailer equipment more than offsets the savings on depreciation of the ion exchange equipment (if one assumes that the contracting firm must charge sufficient fees to allow for only 70% utilization of its portable equipment). Table C.4 also shows that there will be a very slight savings in depreciation cost if the equipment can be utilized at 100% efficiency. Overall, however, these calculations suggest that a portable unit would not attract much venture capital.

For other heavy metal salts – arsenic, antimony, cadmium and mercury – TRW suggested long-term storage, precipitation as the sulfide, precipitation as the hydroxide, or recovery by ion exchange as several candidate means to be used by the NDS. When these metal salts can be recovered economically at the site generating them, by such means as ion exchange, they will not appear as waste materials. Where the wastewater is too contaminated with other waste materials or the recovered metal would have too little value if recovered, the heavy metal solution does indeed become a wastewater. If these heavy metals are already in the insoluble solid form (e.g., sulfide or hydroxide) the only treatment necessary would be to encapsulate and landfill (or store).

One possible means for removing any of the soluble heavy metals from wastewater efficiently enough to meet present (and probably future) concentration criteria would be to precipitate them as the sulfides and encapsulate and landfill or store the sludge. These sulfides also exhibit such a low solubility, that the danger of accidental release of the heavy metal to the environment would be very small. Some of these heavy metals also form water insoluble hydroxides, but the sulfides are generally even less soluble and are more granular (less gel-like) than the hydroxides. Thus they are easier to handle in the filtration step.

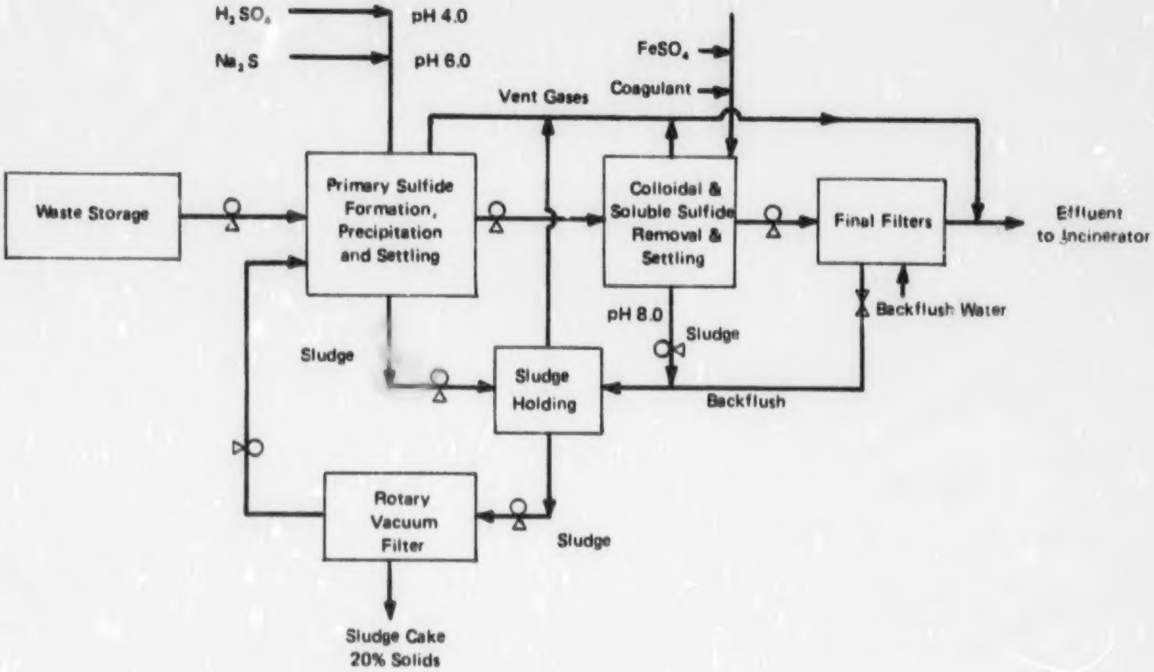
A typical soluble, heavy-metal waste that could be treated by sulfide precipitation is as follows:

10,000 gal/week

2-3% sodium arsenite

1-2% organic arsenites.

The system proposed for this sulfide precipitation is shown in Figure C.5 and the cost calculations in Table C.5.


H_2SO_4
pH 4.0
Na_2S
pH 6.0
$FeSO_4$
Coagulant
Vent Gases
Waste Storage
Primary Sulfide Formation, Precipitation and Settling
Colloidal & Soluble Sulfide Removal & Settling
Final Filters
Effluent to Incinerator
pH 8.0
Sludge
Backflush Water
Sludge
Sludge Holding
Backflush
Rotary Vacuum Filter
Sludge
Sludge Cake
20% Solids

	Purchased Equipment
Waste Storage	$ 6,000
Primary Precipitation & Settling	15,000
Secondary Sulfide Removal	6,500
Sludge Holding	8,500
Rotary Vacuum Filter	20,000
Final Filters	500
Centrifugal Pumps	2,700
pH and Sulfide Electrodes & Instruments	2,000
Sludge Pumps	2,000
Coagulant, $FeSO_4$, Na_2S, Caustic, Acid, Metering Pumps	1,000
Na_2S, $Ca(OH)_2$, $FeSO_4$ Makeup Tanks and Agitators	3,000
Acid Storage	600
Purchased Equipment	$ 67,800 x3
Fixed Capital Investment	$203,400
Rounded to	$200,000

Basis: 2000 gal/day Heavy Metal Waste Solution
20,000 ppm Heavy Metal Content (Arsenic)

FIGURE C.5 DISPOSAL OF HAZARDOUS HEAVY METAL WATER SULFIDE PRECIPITATION OF HEAVY METALS

TABLE C.5

COST OF SULFIDE PRECIPITATION OF HEAVY METALS FROM WASTEWATER

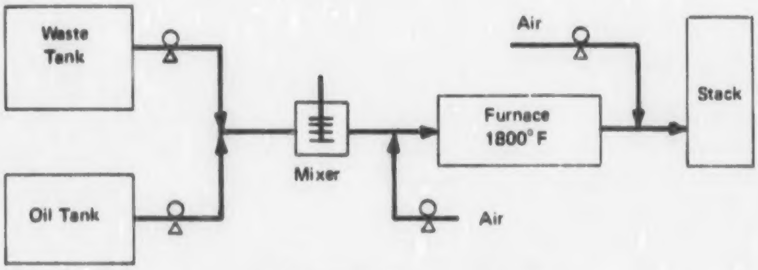
Basis: 2000 gal/day 20,000 ppm Arsenic

Chemicals	**Units/day**		
Na_2S	420 lb/day x $0.80/lb	= 33.60	$48.00/day
H_2SO_4	1100 lb/day x $0.01/lb	= 11.00	
$FeSO_4$	150 lb/day x $0.02/lb	= 3.00	
Coagulant	0.8 lb/day x $0.20/lb	= 0.16	
Utilities			
50 HP @ 1¢/kwh			4.00
Labor			
(Incl. Fringe)	2 men x 8 hrs/day x $5.50/man-hr		88.00
Overhead			
@ 50% Labor			44.00
Depreciation	20% FCI/yr	$40,000/yr	167.00
Maintenance	5% FCI/yr	10,000/yr	42.00
Taxes & Insurance	2% FCI/yr	4,000/yr	17.00
			$410.00/day
			$0.20/gal

Sludge Output 32 ft^3/day

HEAVY METALS WITH ORGANICS

If the waste stream contained organic materials in addition to the heavy metals, the effluent from the precipitation system would have to be burned or treated by a process such as carbon adsorption. A system for incineration of the dilute hydrocarbon waste is shown in Figure C.6 and Table C.6 (Carbon adsorption treatment of this same waste is shown in Figure C.7 and Table C.7.)



Oil Storage Tank	$ 500
Waste Storage Tank	3,000
Oil & Waste Pumps	1,000
In-Line Mixer	300
Furnace	25,000
Secondary Blower	1,000
Stack	2,000
	$32,800
	x2.5 (Furnace x2.2)
Fixed Capital Investment	$82,000

Basis: 2000 gal/day 2% Hydrocarbon (Non-chlorinated)
400 gal/day Oil Rate (50 gal/hr = 7.25 MM Btu/hr)

FIGURE C.6 INCINERATION OF DILUTE HYDROCARBON

TABLE C.6

COST OF INCINERATION OF DILUTE HYDROCARBON

Basis: 2000 gpd 2% hydrocarbon (non-chlorinated)

Utilities			
Oil	400 gal/day x $0.10/gal		$40/day
Power	25 HP		2
Labor			
2 man-hrs/day x $5.50/man-hr			11
Overhead @ 50% Labor			6
Depreciation	20% FCI/yr	$16,400/yr	68
Maintenance	5% FCI/yr	4,100/yr	17
Insurance & Taxes	2% FCI/yr	1,600/yr	7
			$151/day
			$0.08/gal

TABLE C.7

COST OF DILUTE HYDROCARBON TREATMENT BY ACTIVATED CARBON

Basis: 2000 gal/day dilute (2% by weight) hydrocarbon
240 days/year 24 hrs/day
Fixed Capital Investment $64,000

Cost Item	Units/day	$/Unit	$/day
Activated Carbon	6700 lb	0.10*	670.0
Power	240 kwh		2.4
Labor (Incl. Fringe)	2 man-hrs	5.50	11.0
Overhead (Admin.)	50% Labor		5.5
Depreciation	20% FCI/yr	$12,800/yr	62.7
Maintenance	5% FCI/yr	3,200/yr	15.7
Taxes & Insurance	2% FCI/yr	1,300/yr	6.4
			$773.7/day
			$0.39/gal

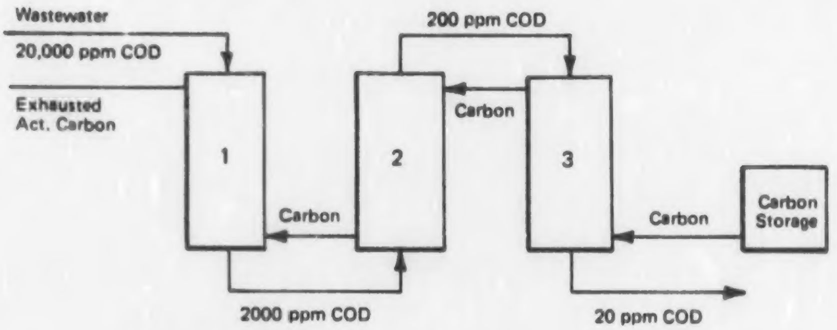
* Regenerated On-site. Regeneration by Activated Carbon Supplier would cost about $0.30 per lb.

COST OF ACTIVATED CARBON REGENERATION

Basis: Carbon Regeneration System Capital Investment $300,000 (1972)
6,700 lbs/day activated carbon, 804 tons/yr ($200,000 in 1968)

Cost Item	Units/yr	$/unit	$/year	$/day
Makeup Carbon at 6% Loss	48 tons	600/ton	28,800	
Labor 24-man-hrs/day		5.50/man-hr	32,000	
Fuel			3,500	
Power			1.400	
Overhead (Admin)			16,000	
Depreciation at 20% FCI/yr			60,000	
Maintenance			6,000	
Taxes & Insurance 2% FCI/yr			6,000	
			$153,700	$640/day
				$0.10/lb Carbon

* Lake Tahoe Unit


Wastewater
20,000 ppm COD
Exhausted
Act. Carbon
200 ppm COD
1
2
3
Carbon
Carbon
Carbon
Carbon
Storage
2000 ppm COD
20 ppm COD

Waste Storage Tank		2,000
Adsorption Towers		6,200
Carbon Conveyors		4,400
New Carbon Storage		1,000
Pumps		2,200
Valves		2,000
Controls		2,500
Spent Carbon Storage		1,000
	Purchased Equipment	21,300
		x3
	Fixed Capital Investment	$63,900
	Rounded to	$64,000

Basis: 2000 gal/day Wastewater containing 2% hydrocarbon
240 days/yr at 24 hrs/day
COD = chemical oxygen demand

FIGURE C.7 DILUTE HYDROCARBON REMOVAL FROM WASTEWATER BY ACTIVATED CARBON

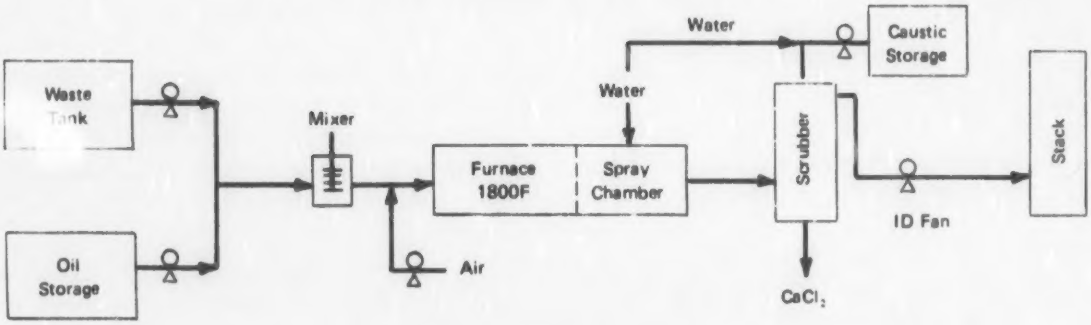
If the dilute hydrocarbon contains chlorine or nitrate, it would be necessary to scrub the flue gas. This system (shown in Figure C.8 and Table C.8) also could be used with minor modification for incineration of explosive wastes after the explosive is slurried in water.

TABLE C.8

COST OF INCINERATION OF DILUTE HYDROCARBON CONTAINING HALOGEN

Basis: 2,000 gal/day 2% hydrocarbon (chlorinated)

Chemicals			
Casustic Soda	300 lb/day	@ 4¢ lb	$12.00/day
Utilities			
Cooling Water	100 M gal/day	@ 5¢/M gal	5.00
Fuel	400 gal/day	@ 10¢/gal	40.00
Power			1.00
Labor (Incl. Fringe)	12 man-hrs/day x $5.50/man-hr		66.00
Overhead (at 50% Labor)			33.00
Depreciation	20% FCI/yr	$34,000/yr	142.00
Maintenance	5% FCI/yr	8,500	35.00
Taxes & Insurance	2% FCI/yr	3,400	14.00
			$348/day
			0.17/gal


Water
Caustic Storage
Waste Tank
Water
Mixer
Furnace 1800F
Spray Chamber
Scrubber
Stack
ID Fan
Oil Storage
Air
$CaCl_2$

Oil Storage Tank	$ 500
Waste Storage (or Mixing) Tank	3,000
Oil & Waste Pumps	1,000
In-Line Mixer	300
Furnace	25,000
Spray Chamber	10,000
Scrubber (Venturi)	18,000
Scrubber I. D. Fan	5,000
Caustic Soda Storage Tank	2,000
Stack	3,000
Pumps	1,500
	$ 69,300
	x2.5
Fixed Capital Investment	$173,250
Round to	$170,000

Basis: 2000 gal/day 2% Hydrocarbon (Chlorinated)
400 gal/day Fuel Oil Rate

FIGURE C.8 INCINERATION OF DILUTE HYDROCARBONS CONTAINING HALOGEN

DISPOSAL OF HEAVY METAL SLUDGES

The sludges produced by the precipitation of the heavy metals in general will not be economically recoverable on a continuing basis. Their disposal will consist of on-site encapsulation in asphalt, waste resin, or polymer. Volatile sulfides that would have too high a vapor pressure at the temperature of the molten tar or resin, would be encapsulated in concrete.

For the tar or polymer encapsulation, we visualize using still bottoms or other tar residues, some at zero cost, but on the average at 1¢/pound. Also, we understand that off-standard polymers are available at 1¢/pound. This waste would be cast into fiber or used (waste) steel 55-gallon drums (assumed to be available at about $2 each).

For encapsulation in cement, we visualize using dilute metal sulfide or hydroxide as the water to form the concrete. A portable cement mixer, of the type used at small construction sites, would be used to mix the cement and the water containing the insolubilized metal, and the mixture would then be cast into fiber drums or used (waste) steel drums.

Table C.9 summarizes the costs for several methods of encapsulating sludge cakes of a typical concentration, 20%. These costs represent the operating experience of two companies and ADL's estimates for a volatile and non-volatile sludge.

TABLE C.9

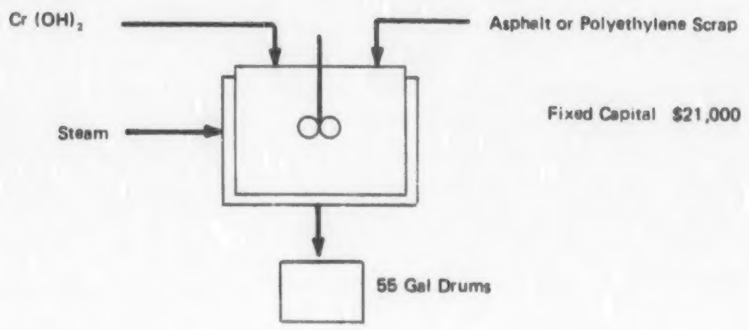
DISPOSAL OF FILTERED HEAVY METAL SLUDGES

Basis: Sludge Cake 20% Solids by Weight

Process	Disposal Cost (¢ Per Gallon Wet Sludge)
Company A	8-10
Company B	3-12
Polymer Encapsulation & Landfill (Fig. C.9)	25
Cement Encapsulation & Burial Onsite*	10

* Volatile sludges only.

Figure C.9 shows the capital costs and operating costs associated with the asphalt encapsulation as estimated by ADL. The cement encapsulation process costs are based on the cost of an outside contractor pouring cement at $23/cubic yard (5-yd minimum) into used steel drums or fiber drums, and burying it. Unfortunately, the dilute slurry of metal sulfides would increase in volume (1:65) in making the concrete, so the cost of excavation and backfill (at $3/cubic yard and $2/cubic yard, respectively) would represent one-third of the total cost of 25¢/gallon.


$Cr(OH)_2$
Asphalt or Polyethylene Scrap
Steam
55 Gal Drums

Fixed Capital $21,000

Encapsulation Cost

Raw Materials, Asphalt 1000 lb @ 1¢ / lb	=	$10/day
Utilities, Steam 10,000 lbs		10
Labor 4 man-hours/day x 5.50		22
Overhead		11
Depreciation, Maintenance, Taxes & Insurance		15
Drums @ 2 ea., 3/day		6
		$74/day
		$0.65/ft³ Sludge

Burial Cost

Excavation: 2 yds x $5/yd	=	$10/day
Back Fill		5
		$15/day
Total for Encapsulation & Landfill		$89/day
		$0.77/ft³ Sludge
		$0.103/gal Sludge

Basis: 115 ft³/day Chrome Sludge (1720 lb/day $Cr(OH)_2$)

FIGURE C.9 ASPHALT ENCAPSULATION OF CHROME WASTE SLUDGE & BURIAL (20% Solids)

CONCENTRATED CYANIDE WASTES

The treatments applicable to concentrated cyanide waste include acid decomposition of the cyanide and subsequent incineration of the HCN, Du Pont's Kastone hydrogen peroxide method,* and the Schindewolf thermal decomposition process.**

For our examples we have compared the destruction of the cyanide radical by the conventional caustic-chlorine oxidation (Figure C.10 and Table C.10) with a 2-step process that involves acidification, incineration of the HCN gas, heavy metal treatment, and secondary cyanide treatment by alkaline chlorination (Figure C.11 and Table C.11). The 2-step process requires less chemicals, but more labor and investment and on the whole is a more expensive process. It would have the advantage of producing less secondary effluent (NaCl). If a suitable kiln or furnace were available at the site for safely burning the HCN, the capital investment could be reduced by 15%, but this process would be more expensive because of the labor required for two stages rather than one stage of treatment.

TABLE C.10

COST OF TREATMENT OF CONCENTRATED CYANIDE WASTE BY CHLORINATIO

Basis: 5,000 gal/week 1,000 gal/day (1 batch/day)
7,000 ppm copper cyanide 1,000 ppm sodium cyanide
Fixed Capital Investment $100,000

	Units/day	$/Unit	$/day
Chemicals			
Caustic	95	0.03	2.8
Chlorine	227	0.07	15.9
Utilities			
Power	150 Kwh	0.01	1.5
Cooling Water (Mgal)	1.5	0.05	0.8
Labor 4 man-hrs/day			22.0
Overhead 50% of labor			11.0
Depreciation	20% FCI/yr	$20,000/yr	83.3
Maintenance	5% FCI/yr	$ 5,000/yr	20.8
Taxes & Insurance	2% FCI/yr	$ 2,000/yr	8.3
			$166.4/day
			$ 0.17/gal

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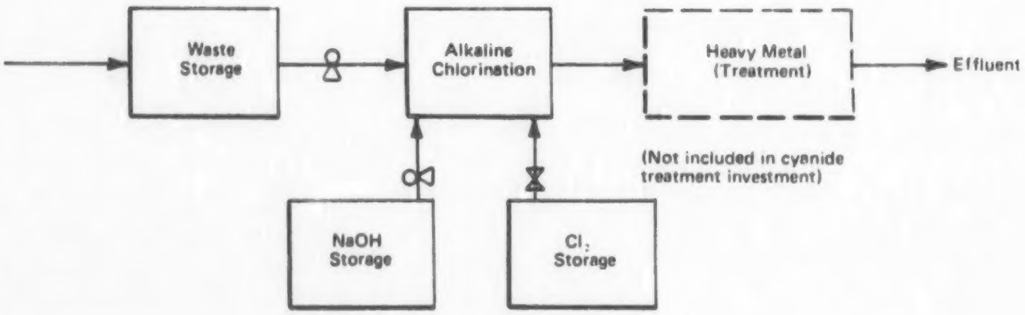
* *Chemical Week*, December 16, 1970, p. 54.

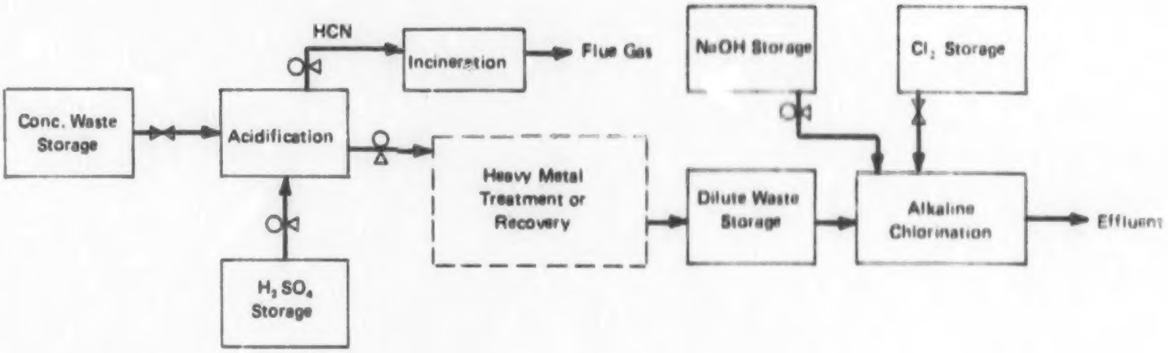
** *Chemical Week*, December 20, 1972, p. 32.


Waste Storage
Alkaline Chlorination
Heavy Metal (Treatment)
Effluent
(Not included in cyanide treatment investment)
NaOH Storage
Cl_2 Storage

Waste Storage (5,000 gal. Carbon Steel)	2,500
Chlorine Storage (Included in Cl_2 Cost)	–
Caustic Storage (500 gal. Carbon Steel)	500
Chlorine and Caustic Metering Systems	3,000
Waste Transfer Pump	700
pH and Redox Control Systems	1.500
Alkaline Chlorination Reactor with Cooling Coils (1,500 gal)	22,000
Purchased Equipment	28,400
	x3.5
Fixed Capital Investment	99,400
Rounded to	$100,000

Basis: 5000 gal/week, 5 Batches of 1000 gal/week, 48 weeks/year
7000 ppm copper cyanide 1000 ppm sodium cyanide

FIGURE C.10 CONCENTRATED CYANIDE WASTE TREATMENT BY CHLORINATION


HCN
Incineration
Flue Gas
NaOH Storage
Cl_2 Storage
Conc. Waste Storage
Acidification
Heavy Metal Treatment or Recovery
Dilute Waste Storage
Alkaline Chlorination
Effluent
H_2SO_4 Storage

Conc. Waste Storage	$ 2,500
Dilute Waste Storage	2,500
Sulfuric Acid Storage	300
Chlorine Storage (Included in Chlorine Cost)	---
Caustic Storage	300
Acid & Chlorin. Reactor	21,000
Vacuum Pump	1,500
Gas Incineration System	6,500
Incineration Low Temp. HCN Shutoff	1,000
Acid Metering Pump	700
Caustic and Chlorine Metering Systems	2,500
pH Control System	1,000
Purchased Equipment Cost	42,500
	x3.5
Fixed Capital Investment	$148,750
Round to	$150,000

Basis: 5000 gal/week (1000 gal/day) Batch Treatment
7000 ppm Copper Cyanide, 1000 ppm Sodium Cyanide

FIGURE C.11 CONCENTRATED CYANIDE WASTE TREATMENT BY ACIDIFICATION AND CHLORINATION

TABLE C.11

COST OF CONCENTRATED CYANIDE WASTE TREATMENT – 2 STAGES
(acidification & chlorination)

Basis: 5,000 gal/week, 1,000 gal/day
7,000 ppm Copper Cyanide, 1,000 ppm Sodium Cyanide
Batch Treatment, Capital Investment $150,000

	Units/day	$/Unit	$/day	
Chemicals				
Sulfuric Acid	58 lb	0.02	1.16	1.7
Caustic Soda	2.6	0.03	0.08	
Chlorine	6.1	0.07	0.43	
Utilities				
Power	300 Kwh	0.01		3.0
Steam	0.3 MMBtu	1.00		0.3
Gas	4.2 MMBtu	0.32		1.3
Labor	8 man-hrs/day	5.50		44.0
Overhead	50% labor			22.0
Depreciation	20% FCI/yr	30,000/yr		125.0
Maintenance	5% FCI/yr	7,500/yr		31.0
Taxes & Insurance	2% FCI/yr	3,000/yr		12.5
				$241/day $0.24/gal

DILUTE CYANIDE WASTES

Much of the cyanide wastes occurs as effluents from the plating or metal recovery industries. These wastes would have to be treated for both the cyanide and heavy metals.

The concentration of the cyanide and heavy metal and the value of these compounds would influence the selection of the waste treatment system. If the cyanide and heavy metal are not economically recoverable (e.g., by ion exchange), the cyanide radical would be destroyed and the heavy metal precipitated and disposed of as sludge.

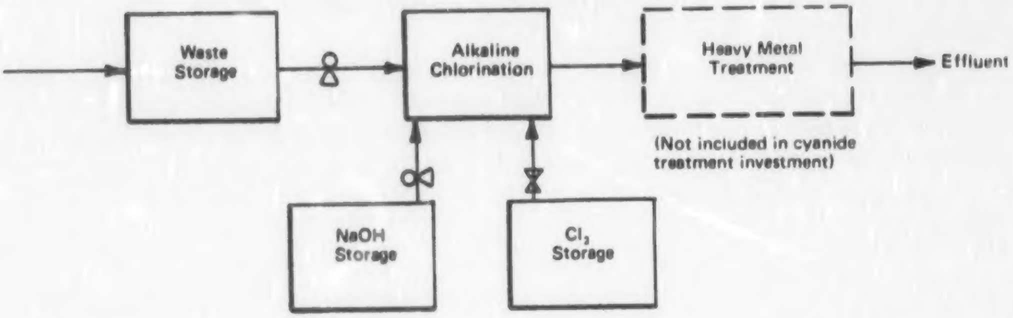
In treating a dilute cyanide waste, one can use hypochlorite, or caustic and chlorine, to oxidize the cyanide to cyanate or to nitrogen and carbonate. This oxidation may be done in either a batch or a continuous system with sufficient residence time. Relatively small volumes probably would be treated in a batch process. In Figure C.12 and Table C.12, we have depicted a batch process for the total oxidation of a dilute cyanide by caustic and chlorine followed by heavy-metal removal.

TABLE C.12

COST OF DILUTE CYANIDE WASTE TREATMENT

Basis: 5000 gal/week 2 Batches/week 48 weeks/year
100 ppm $Cu(CN)_2$ 100 ppm NaCN Capital Investment $95,000

	Units/Batch	$/unit	$/batch	$/week
Chemicals				
Caustic	6.4	0.02	0.13	
Chlorine	15.3	0.10	1.53	5.0
Utilities				
Power	200 Kwh	0.01	2.00	4.0
Labor	4 man-hrs/batch		22.00	44.0
Overhead	50% Labor		11.00	22.0
Depreciation	20% FCI	$19,000/yr		396.0
Maintenance	5% FCI	5,000		104.0
Taxes & Insurance	2% FCI	2,000/yr		40.0
				$615/week
				$0.12/gal.


Waste Storage
Alkaline Chlorination
Heavy Metal Treatment
Effluent
(Not included in cyanide treatment investment)
NaOH Storage
Cl_2 Storage

Waste Storage (5000 gal. carbon steel)	2,500
Chlorine Storage	--
Caustic Storage (200 gal. carbon steel)	300
Chlorine and Caustic Metering Systems	2,500
Waste Transfer Pump	700
pH and Redox Control Systems	1,200
Alkaline Chlorination Reactor (3000 gal.)	20,000
Purchased Equipment	27,200
	x3.5
Fixed Capital Investment	$95,270
Rounded to	$95,000

Basis: 5,000 gal/week, 2 Batches of 2,500 gal/week, 48 weeks/year
100 ppm Copper Cyanide 100 ppm Sodium Cyanide

FIGURE C.12 DILUTE CYANIDE WASTE TREATMENT

CHLORINATED HYDROCARBON WASTES

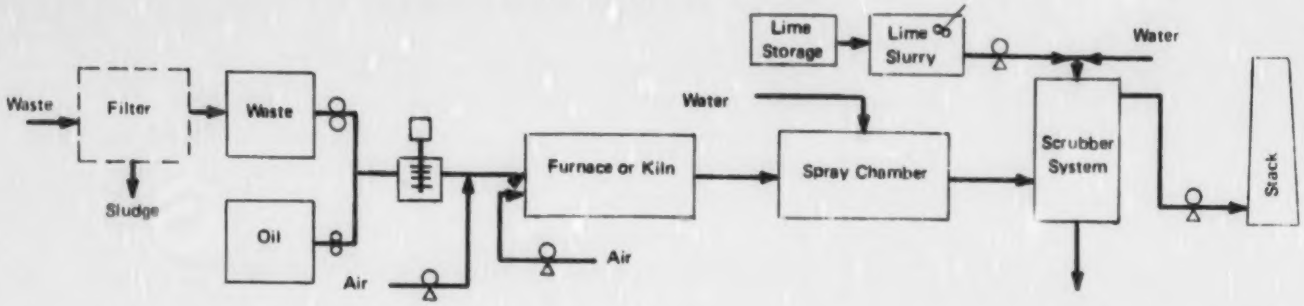
This category of chlorinated hydrocarbons includes many types of materials, including insecticides, chlorinated solvents, and power-transformer heat-transfer oil (PCB's). These solvents may contain oil, metal cuttings or other solid materials. Waste chlorinated hydrocarbons that contain no solid materials could be incinerated directly in a furnace and the flue gas scrubbed (Figure C.13 and Table C.13).

TABLE C.13

INCINERATION OF CHLORINATED HYDROCARBON LIQUID

Basis: 3,000 gal/day chlorinated hydrocarbon
Operation 24 hrs/day, 5 days per week (240 days/yr)
Fixed Capital Inv. $900,000

Cost Item		Units/hr.	Units/day	Units/yr.	Unit Cost	$/day
Lime Hydrate		2,110 lb	50,640 lb		0.012	608
Cooling Water		70,000 gal	1,680,000 gal		0.05	84
Fuel		180 gal	4,320 gal		0.10	432
Power		300 Kwh	7,200 Kwh		0.01	72
Labor (Incl. Fringe)			16 hrs/day		$5.50	88
Overhead			50% labor		–	44
Depreciation	(20% FCI/yr)			$208,000/yr		867
Maintenance	(5% FCI/yr)			$ 52,000/yr		217
Insurance & Taxes	(2% FCI/yr)			$ 21,000/yr		87
					Total	$2,499/day
					Savings	$2,500/day
						$0.83/gal


Lime Storage
Lime Slurry
Water
Waste
Filter
Sludge
Waste
Oil
Air
Furnace or Kiln
Air
Water
Spray Chamber
Scrubber System
Stack

I. Liquid Chlorinated Hydrocarbons

Fuel Storage	$ 6,000
Waste Storage	28,000
Fuel Metering Pump	500
Waste Metering Pump (Alloy)	700
In-Line Mixer	400
Air Compressor	10,000
FD Fan (Included in Furnace)	---
Furnace & Afterburner (to 2800F)	85,000
Spray Cooling Chamber	20,000
Scrubber	100,000
Scrubber I.D. Fan	10,000
Lime Storage & Slurry System	10,000
Slurry Pump & Flowmeter	600
Stack	8,000
Total Purchased Equipment	$279,200
	x3.5
Fixed Capital (Excl. Cool Tower)	$977,000
Cooling Tower (Installed)	60,000
Total Fixed Capital Investment	$1,037,000
Round to	$1,040,000

Basis: 3000 gal/day, 24 hrs/day
240 days/year

FIGURE C.13 INCINERATION COST OF CHLORINATED HYDROCARBON LIQUIDS – CAPITAL COSTS

ORGANIC WASTE REQUIRING A KILN

Liquid chlorinated hydrocarbons that contain solid matter would have to be filtered and the sludge and clarified liquid fed separately to a kiln (Figure C.14 and Table C.14). The flue gas from the furnace or kiln would be cooled in a spray chamber then scrubbed with dilute alkali in a two-stage scrubbing system (venturi + packed column). Solid chlorinated hydrocarbons would be fed directly to the kiln.

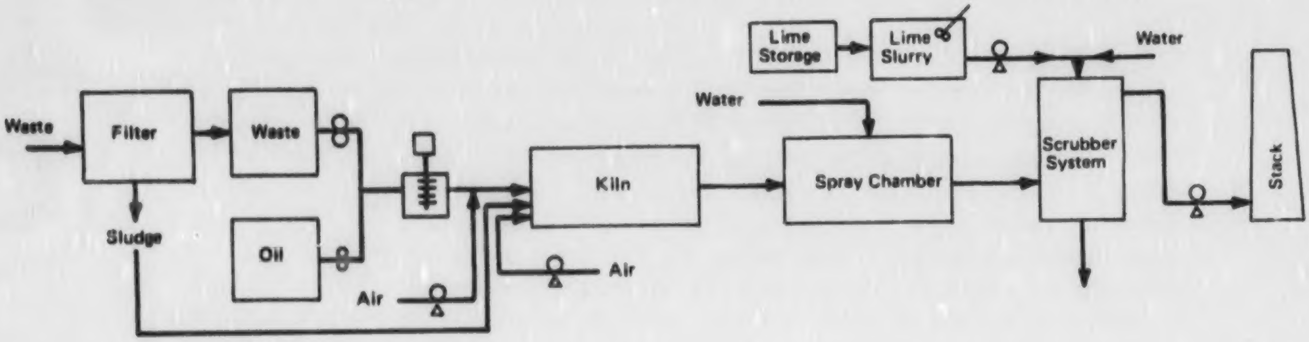
For our example we used polychlorinated biphenyls with and without a solid contaminant.

TABLE C.14

INCINERATION OF CHLORINATED HYDROCARBON SLURRY

Basis: 3,000 gal/day chlorinated hydrocarbon and solids
Operation 24 hrs/day, 5 days per week (240 days/yr)
Fixed Capital Investment $1,400,000

Cost Item	Units/hr	Units/day	Unit Cost	$/day
Lime Hydrate	2,110 lb	50,640	0.012	608
Cooling Water	70,000 gal	1,680,000	0.05	84
Fuel	180 gal	4,320	0.01	432
Power	350 kw	8,400	0.01	84
Labor (Incl. fringe)		32 hrs/day	5.50	176
Overhead				88
Depreciation	20% FCI/yr	$252,000/yr		1,050
Maintenance	5% FCI/yr	63,000/yr		262
Insurance & Taxes	2% FCI/yr	25,000/yr		104
				$2,888/day
				$0.96/gal


Lime Storage
Lime Slurry
Water
Water
Waste
Filter
Waste
Sludge
Oil
Air
Kiln
Air
Spray Chamber
Scrubber System
Stack

II. Chlorinated Hydrocarbon Slurries	Purchased Equipment
Fuel Storage	$ 6,000
Waste Storage & Settling Tank	20,000
Sludge Conveyor	2,000
2 Filter Pumps	2,000
Shell Type Filter (Stainless Screens)	4,500
Filtered Waste Storage	28,000
Fuel Metering Pump	300
Waste Metering Pumps	1,700
In-Line Mixer	400
Air Compressor	10,000
Air Blower (Included with Kiln)	--
Rotary Kiln (Including Feed Mechanisms) and Afterburner	120,000
Spray Cooling Chamber	20,000
Scrubber System	100,000
Scrubber I.D. Fan	10,000
Lime Storage and Slurry System	10,000
Lime Slurry Pump and Flowmeter	600
Stack	8,000
Total Purchased Equipment	$343,500 x3.5
Fixed Capital Investment (Excl. Cool. Tower)	$1,202,000
Cooling Tower Installed	60,000
Total Fixed Capital Investment	$1,262,000
Round to	$1,260,000

Basis: 3000 gal/day Chlorinated Hydrocarbon Slurry
Operation 24 hrs/day, 5 days per week (240 days/yr)

FIGURE C.14 INCINERATION OF CHLORINATED HYDROCARBON SLURRIES – CAPITAL COSTS

DISINTEGRATION AND INCINERATION OF INSECTICIDE DRUMS AND PAILS

We have considered the economics of a portable disintegrator for insecticide containers. We have based it, in part, on our understanding of such a unit as conceptualized by the Chemagro Company. In its letter to the President's Cabinet Committee on the Environment,* Chemagro proposed a portable insecticide-can disintegrator made up of: (1) a hammer mill, (2) an exhaust fan to prevent the dust from leaving the hammer mill via a negative pressure, (3) a high-temperature incinerator for the dust laden exhaust air and (4) appropriate scrubbing system, so one could disintegrate cans and at the same time incinerate the pesticide residues contained in the cans. The company suggested that such a portable unit would cost on the order of $300,000, and that it could go to the various insecticide producing companies and distributors, who are accumulating 30- and 50-gallon drums and 1- and 5-gallon pails at the rate of 250,000 and 40 million, respectively, each year.

We have not seen Chemagro's specific plans for such a unit but understand that it has demonstrated its feasibility in a stationary hammer mill and stationary incinerator scrubbing system.

We have made some very cursory economic calculations based on the following assumptions:

1. The hammer mill is operated in such fashion that it requires an air flow-through rate of 60 volumes/minute for incineration (it turns out that this assumption is not a critical one), and that the air is heated to 2100F before being discharged to a scrubber and to the atmosphere;

2. The unit costs $300,000;

3. It takes two men to operate the unit – one to feed the cans to the hammer mill, and one with a forklift truck collecting the cans on the storage lot and bringing them to the unit; and

4. The feed rate is equivalent to one 50-gallon can per minute, or 14.4 tons/day of metal.

Our calculations (Table C.15) indicate that fuel is the minor part of the operating cost and that the fixed charges dominate all other costs. Furthermore, the economics of the entire system are completely dictated by the net value of the scrap that is collected as a result of this operation. Chemagro's letter to the Government indicated that the scrap was

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* Letter to the President's Cabinet Committee on the Environment, Subcommittee on Pesticides, Federal Working Group on Pesticides Management, by Dr. Robert C. Scott, Vice President of Manufacturing, Chemagro Division of Baychem Corporation, February 9, 1972.

TABLE C.15

COST OF WASTE WATER CONCENTRATION BY EVAPORATION

Basis: Evaporation of 1,000 – 10,000 gallons water/day
8 hrs/day operation, 260 days per year
Submerged Combustion Evaporation

		Gallons per Day		
		1,000	5,000	10,000
Fixed Capital Investment (FCI)		$75,000	$120,000	$150,000
Operating Cost	($/1,000 gal.)			
Utilities				
Gas	(at 70¢/1,000 ft.^{3})	6.73	6.73	6.73
Electricity	(at 1¢/Kwh)	0.89	0.89	0.89
Cooling Water	(at 5¢/1,000 gal.)	1.67	1.67	1.67
Labor		44.00	8.80	4.40
Overhead (Admin.)		22.00	4.40	2.20
Depreciation	(at 20% FCI per year)	57.69	18.46	11.54
Maintenance	(at 5% FCI per year)	14.42	4.62	2.88
Insurance	(at 2% FCI per year)	5.77	1.85	1.15
Total Operating Cost ($ per 1,000 gal.)		$153.17	$47.42	$31.46

evaluated by several steel companies as being number 1 grade. This may well be the case for these disintegrated 50-gallon drums; however, we have conservatively assumed that the 5-gallon and 1-gallon pails, being of much thinner steel, would be evaluated as the equivalent of an automotive grade scrap (very thin). This scrap currently sells for $40/ton delivered at the steel mills. However, the market fluctuates violently between $10 and $40/ton, delivered. A further complication is that to get the top price for scrap with a steel mill, one has to ensure delivery of large quantities, on the order of 50,000 tons/year (which is approximately the total market for pesticide cans), although there is no reason why these portable units could not also be used to disintegrate other types of chemical containers and salvage their metal value.

We have very conservatively assumed scrap prices at $15/ton and $10/ton delivery cost to a steel mill for a net of only $5/ton credit to this operation. This gives a net destruction cost of 76¢ for each 50-gallon drum. If one could realize the full $40/ton market price for delivered scrap to the mills, the net price would be $30/ton which would give a $432 credit, or essentially break-even operation for drum destruction. Therefore, any service charge on the drums would be gross profit to the company operating the portable unit.

If the portable unit could be built for $150,000 instead of $300,000 and the economics were evaluated on the basis of one man/shift operating the unit (presumably a second man being provided by the company disposing the pails), the estimated operating cost is only $252/day, with a $72/day credit to the scrap, and a net disposal cost of 37¢/pail. Stated another way, this less expensive operation could break even at scrap values of $27.50/ton (or a net of $17.50/ton to the portable unit operator). (See Table C.16.)

TABLE C.16

PORTABLE INSECTICIDE CAN DESTROYER

(Assumed capacity 3600 lb/metal hour, 1 shift/day operation)

Fuel, 4.4 MM Btu/hr @ 15¢/gal	$ 6
Labor, 2 men/shift @ $3.50/hr	88
Overhead	44
Depreciation, $300,000 investment @ 5 years	240
Maintenance @ 5% or $15,000/yr	60
	$ 438/day or $0.91/drum
Credit for 14.4 tons/day steel @ $15/ton delivered*	-72
	$ 366 or net cost $0.76/drum

*Assumes $10/ton delivery cost to steel mill.

Obviously, these economics are not accurate enough to draw any general conclusions other than to say that the economics of a portable insecticide can destroyer are grossly determined by: (a) the capital cost of the equipment and (b) the net scrap value for the cans destroyed.

APPENDIX D

RISK ANALYSIS

GENERAL METHODOLOGY

To arrive at the total risk of a hazardous waste disposal scheme, one must divide the scheme into operational steps for which individual risks can be calculated and finally summed. For example, a disposal scheme may consist of the following steps: wastes are stored at the source, then transferred to tank cars, transported by rail to a local disposal site, transferred to holding storage tanks at the disposal site and finally processed. The degree of risk to which society is exposed from such an operation is a function of the probability that an accident will occur during any one of these steps, the probability of waste release given an accident, and the probability of creating one or more hazards to society given a release.

In arriving at the probability of an accident, one employs previous statistics on accidents in similar operations. The next step is to determine the probability of release given an accident and finally the probability of fatality or injury or permanent environmental damage given the release of waste. This type of information can be derived only from technical considerations, and depends on such factors as:

- The physical, chemical and biological properties of the waste;
- Expected quantity and rate of release;
- Population density along route of travel and near generating and disposal sites;
- Protective measures taken to prevent the accidental release of waste (i.e., method of packaging, transfer procedures, etc.);
- Ease of neutralization and/or containment of the waste;
- Contingency planning.

Our discussion in Part 2 showed that for the purposes of this study, transportation accidents appear to be the decisive factor in this risk analysis. The methodology derived here is, therefore, essentially for transport accidents.

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RISK TO HUMAN LIFE

Definition of Acceptable Risk

There is evidence to suggest that society will accept a technological risk if it is comparable to or lower than the risk to which the population is exposed in its everyday life. Starr[1,2] has shown that, for the U.S. population, the statistical risk of death from disease and accident (10^{-6} fatality/person-hr exposure) appears to be a psychological yardstick for establishing the level of acceptability of other risks.* He also showed that the public is willing to accept "voluntary" risks (e.g., hunting, skiing, smoking, etc.) roughly 1000 times greater than "involuntary" risks (e.g., living near a flammable liquid storage tank or a nuclear reactor). Other workers[3,4,5] have also used similar units (e.g., fatality/person-hr exposure) for estimating risk.

We have collected or calculated the magnitudes of risks to which the U.S. population is generally exposed in its everyday life. These are given in Table D.1 and compared with some values for the United Kingdom.

TABLE D.1

TYPICAL VALUES OF RISK
(fatality/person-hr exposure)

Risk of Death From	United States	United Kingdom
disease and accident	10^{-6} [1,2]	
fires at home	0.4×10^{-8}	0.1×10^{-8} [7]
accidents at home	2.1×10^{-8}	3×10^{-8} [3]
manufacturing accidents	3×10^{-8} [6]	
floods	2.5×10^{-10} [1,2]	

To explain the meaning of these risk levels, one can calculate the expected reduction in lifetime for an individual continually exposed (for his entire life) to a hazard that may lead to a fatality. The expected lifetime reductions give a basis for considering attitudes toward risk. As shown in Table D.2, a risk of 10^{-10} fatality per person-hour of exposure is practically insignificant, costing, at most, 1 to 3 days in a life of 60-80 years. A risk of 10^{-9} fatality per person-hour of exposure is not insignificant, but the times involved are small enough so individuals are generally willing to accept it. However, a risk of 10^{-8} fatality per person-hour may be marginally acceptable and 10^{-7} fatality per person-hour is clearly unacceptable unless there are considerable justifications or benefits for the individual involved.

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* Starr recognized that it would be more useful to use a yardstick that includes all injuries (which are 100 to 1000 times as numerous as deaths). However, data on injuries are not as available as those on fatalities, are not as trustworthy, and are much less susceptible to useful analysis.

From Table D.2, it can be inferred that many, perhaps most, people who are involuntarily exposed to a hazard would accept a risk level of 10^{-9} fatality per person-hour of exposure or less as "very small" and would consider 10^{-7} fatality or more per person-hour as not "very small," if these risks were shown in terms of reduction of lifetime. Thus the risk analysis task became one of determining whether a particular disposal scheme would entail a risk of less than or more than 10^{-9} fatality per person-hour of exposure.

TABLE D.2

EXPECTED REDUCTION IN LIFETIME FROM A CONTINUOUS, LIFELONG, THREAT OF FATALITY

Probability of Fatality per Hour of Exposure	Expected Recurrence Interval (Years)	Expected Reduction in Lifetime			
		(40)*	(60)	(80)	(100)
10^{-10}	1,140,771	12 hrs	1.2 days	2.1 days	3.2 days
10^{-9}	114,077	5.1 days	11.2 days	20.5 days	1.1 mos.
10^{-8}	11,408	1.7 mos.	3.8 mos.	6.7 mos.	10.4 mos.
10^{-7}	1,141	1.4 yrs.	3.0 yrs.	5.2 yrs.	8.1 yrs.
10^{-6}	114	10.4 yrs.	20.7 yrs.	33.0 yrs.	46.7 yrs.
10^{-5}	11.4	31.1 yrs	50.4 yrs	70.0 yrs.	89.8 yrs.

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*Expected Lifetime without Threat (Years)

Calculating Risk from Fires or Explosions

In calculating risks from accidents resulting in fire, explosion, radioactivity or toxic gas release, a parameter essential for the risk calculation is the "kill radius" which determines the "kill area" of the particular hazard. The "kill area" is that within which humans will die (or assume they will die) as a result of the accident and the subsequent release of the hazardous waste. It should be pointed out that quite often, in making its decision to accept or reject a particular risk, society assumes death for all who are exposed even though death is not likely to occur.

Kill Radius for Fires. If a combustible waste should accidentally spill and ignite, the lethal thermal radiation flux (Btu/hr-ft^2) from the resulting fire will define the kill radius. We selected a thermal radiation flux of 10,000 Btu/hr-ft^2 as the lethal threshold. At this level, clothing, frame homes and vegetation would ignite and endanger the life of anyone present. Although lower levels of thermal radiation can cause severe burns and result in death upon long exposure, we assume that people exposed to lower levels of radiation will generally take shelter and shield themselves from thermal radiation by simply standing behind a wall, a tree or a vehicle.

A method of calculating radiation flux for any separation distance, fire size, and fuel has been developed.[8] If a massive vehicle rupture that spills all the fuel instantaneously (the worst case) is assumed, the farthest distance at which the lethal radiation flux will be felt can be calculated.

To analyze the worst case, we assumed that the volume spilled covers the area necessary to give a spill depth of 0.5 inch. On this basis, we calculated the thermal radiation flux at different distances for a given set of fire conditions to determine the distance at which the flux is 10,000 Btu/hr-ft^2.

Kill Radius for Explosions. As discussed in Part 2, the kill radius of explosion resulting from the rupture of flammable liquid containers was within the fire kill radius. The Army Material Command has published[9] safe separation distances for various types and quantities of explosives. In our analysis we used as the kill radius the separation distance defined by the Army. We also discounted the fact that any explosion is likely to be damped by the container and concerned ourselves with unconfined explosions since these represent the worst case. For the small quantities of explosive wastes that are expected to be shipped, the AMC Manual recommends an exclusion distance of 500 feet. This was used as the "kill" radius for explosive accidents.

Kill Radius for Radioactive Wastes. The "kill" radius for radioactive chemical spills is not as easily defined as that for explosion or fire. The effect of exposure to radioactive materials varies with the type of radioisotope released, the duration of exposure and the dosage. Furthermore, death from radioactivity is not immediate. However, the public perceives a radioactive spill as fatal to those exposed regardless of the dosage or the exposure duration.

Adams and Stone[10] indicate that for releases up to 1000 Ci of ^{131}I, very few casualties would be expected beyond one mile. We have employed a "kill" radius of two miles in our analysis, which is quite conservative considering the small amounts of radioactive wastes expected to be shipped and the low radiation levels that would be released in an accident. These levels are expected to be much less than the 1000 Ci of ^{131}I that would be typically released in a major nuclear reactor failure.

"Kill" Radius for Toxic Gases. The toxic gaseous wastes identified in this study included CW agents. Unlike the dispersion of gases in air, the dispersion of CW aerosols in air is difficult to predict theoretically since the aerosol persists for many days.

The results of military tests on dispersion of CW agents are classified. Published data[11] indicate that "under favorable meteorological conditions, the detonation or vaporization cloud may spread up to 30 kilometers from the point of origin. Beyond that range, concentrations may still be present which lead to combat incapacity."

It appears that a conservative estimate of the size of a vapor cloud from a CW gas release would be 40 miles (64 km) long and 5 miles (8 km) wide, giving a "kill" area of 200 square miles.

Estimating the Probable Risk. Once the kill radius, R, is known, one can estimate the probable risk incurred from transporting a flammable or explosive radioactive material along some route of length L and population density ρ. As long as the route length is much larger than the kill radius (which it almost always is), the total number of people who could be exposed to the fire* hazard is $2RL\rho$. At any given moment, however, only those people within a distance R of the truck transporting the hazard will be exposed to risk. This latter number of people is equal to

$$\pi R^2 \rho P(\rho)$$

where:

πR^2 = circle whose center point is the truck transporting the hazardous waste and whose radius is equal to the kill radius.

ρ = population density along route.

$P(\rho)$ = probability of a given person's being present when the accident occurs.

By definition $\pi R^2 \rho P(\rho)$ people will become fatalities should an accident occur.

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* This applies equally to explosives and radioactive release.

The probabilistic expected value of fires per year is given by:

$$\frac{\text{fires}}{\text{year}} = P(a) \cdot L \cdot n \cdot P(f/a)$$

where:

$P(a)$ = probability of an accident per vehicle mile (derived from statistical data).

L = route length (miles).

n = number of trips per year.

$P(f/a)$ = probability of a fire, given an accident.

Each person within the area exposed to the hazard of possible fire, explosion, or radioactive release is present in that area for some fraction (hours) of a year given by $8760\ P(\rho)$. From the point of view of each individual present, whenever he is within the exposed area he is exposed to the risk of a vehicle passing by and having an accident. Thus, the possible number of exposure-hours is equal to the number of hours in a year times the population density along the route times the probabilistic value of some segment of the population being within the risk area when the accident occurs, or

$$\text{Exposure-hours/year} = 8760\,(2RL\rho)P(\rho)$$

We can now calculate fatalities per exposure-hour as follows:

$$\text{Fatalities per Exposure-hour} = \frac{\text{Fires, Explosions or Radioactive Releases per year} \times \text{Fatalities per Fire, Explosion or Radioactive Release}}{\text{Exposure-hours per year}}$$

Or:

$$\text{Fatalities per Exposure-hour} = \frac{[P(a) \cdot L \cdot n \cdot P(f/a)]\ [\pi R^2 \rho) \cdot P(\rho)]}{8760 \cdot (2RL\rho) \cdot P(\rho)}$$

Which reduces to:

$$\frac{P(a) \times P(f/a) \times nLF}{HT} = \text{fatalities/exposure-hour}$$

where:

$P(a)$ = probability of an accident per vehicle mile per year.
$P(f/a)$ = probability of a fire (explosion) given an accident.
n = number of trips per year.
L = length of trip (miles).
F = fatalities per fire (explosion or radioactive release) = $(\pi R^2 \rho)P(\rho)$.
H = humans exposed per year = $(2RL\rho)$.
T = exposure hours per person per year = $8760\ P(\rho)$.
R = kill radius.
P = population density per unit area.
$P(\rho)$ = probability of person being within kill radius during accident.

The same equation can be used for estimating the risk of toxic gas release except that a "kill area" is used. The expression for F becomes $(XY\rho)\ P(\rho)$ where X and Y are the width and length, respectively, of the toxic vapor cloud. The expression for H becomes $(2YL\rho)$.

CALCULATION OF WATER POLLUTION RISK

Transport Risk

One unit that may be used for assessing water pollution risk is the probabilistic amount of water that can be polluted given a spill of a hazardous waste. To arrive at this number, the probabilistic quantity of the waste that can be spilled in a year during transportation, Q_{st}, and the acceptable critical concentration level of the waste, C_c, should be found.

The ratio Q_{st}/C_c would then represent the volume of water that would be necessary to dilute the spilled waste to a harmless level of concentration.

A system for ranking hazardous materials was developed by Dawson, et. al.,[12] in which the minimum concentration required to produce a detrimental effect (kill fish, make people sick, upset ecological balance, etc.) was given for a large number of hazardous materials. These minimum concentrations were defined in terms of human toxicity, aquatic toxicity, aesthetic effect, and plant toxicity. The lowest of the toxic critical concentrations was used for C_c (mg/liter) in our analysis.

Q_{st} is the quantity of the hazardous chemical that may be accidentally spilled every year (mg/yr). The value of Q_{st} is derived from the quantity of material shipped per year, the concentration of the hazardous waste as shipped, the probability of an accident in which the material is spilled, and the probability of a spill's reaching a body of water. It can be found from the equation

$$Q_{st} = (q)\ (P_{st})$$

where:

q = the quantity of hazardous material in each shipment
P_{st} = the probability of a spill occurring during transport
$= \left(\frac{\text{spills}}{\text{vehicle-miles}}\right)$ (total miles trans. along route/yr)

The value of P_{st} will depend on the safety record of the mode of transport used (derived from previous statistics) as well as on the distance travelled.

The results for a hypothetical case are shown in Table D.3. These data are based on one plant in the Northeast that produces one million gallons of a 2-3% solution or organic and inorganic arsenites and arsenates every three months. The waste may be shipped to two alternative sites where it is treated by evaporation, encapsulation in pitch, and burial in a land fill. Although the same disposal method is used, the waste may be shipped 100 miles in 30,000-gallon railroad tank cars to site I or trucked 10 miles in 9,000-gallon tank trucks to site II. The results show that from a transportation standpoint, site II presents society a lower risk of pollution than site I.

TABLE D.3

TRANSPORT AND TRANSFER SPILL RISK: HYPOTHETICAL EXAMPLE

	Site I	Site II
Mode of transport	Railroad car	Tank Truck
Distance of travel (miles/trip)	100	10
Trips/yr	133	445
Load/trip (gal)	30,000	9,000
Spills/mile*	1.9×10^{-8}	3.6×10^{-8}
Q_{st}/C_c (liters/yr)	16×10^6	3.2×10^6
Q_{sp}/C_c (liters/yr)	15×10^6	51×10^6
Total (liters/yr)	31×10^6	54.2×10^6

* Statistics from National Tank Truck Carriers Conference, Association of American Railroads and Federal Railroad Administration.

Transfer Risk

In our analysis of risk we excluded data based on spills during transfer operations in part because prudent operation will reduce this risk and in part because transfer risk can be analyzed meaningfully only in terms of a specific site. However, we have described the method, based on the same hypothetical example used to describe transport risk, since it may later be useful to define levels of risk during transfer when specific sites are being considered.

There is a risk of spillage during the transfer of material into and out of the vehicle at the source and at the disposal site. The quantity spilled at each transfer point per year will depend on the number of transfer operations performed per year, the flow rate of the waste during filling and unloading, the probability of spill per operation, and the time that a spill is allowed to continue before it is stopped. This probabilistic spilled quantity can then be used in a "critical concentration analysis" similar to the one described for the transport process, provided that certain assumptions are made regarding the probability of a spill reaching water.

The probabilistic quantity spilled, Q_{sp} (mg of hazardous waste), can be expressed as $Q_{sp} = (N)\ (P_{sp})(m)(t)$

where:

N = the number of transfer operations performed annually.

P_{st} = the probability of a spill occurring during a transfer.

m = the flow rate of water-free hazardous waste (in mg/sec).

t = the average time between occurrence of the spills and stoppage of the spill (sec).

This Q_{sp} can be divided by the critical concentration C_c (mg/liter) to give the volume of water required for dilution annually, assuming again that all liquid spilled finds its way into water.

As a first approximation, we assumed in our hypothetical example that once in every 1000 transfers, the contents of a 20-ft length of 6" ID filling pipe will spill. That is, we took P_{sp} to be 10^{-3} and the product (m) (t) to be the chemical waste content of 25 gallons of waste solution.

The results for the hypothetical problem cited here are also shown in Table D.3. The total environmental damage from transportation and transfer spills is also given. It appears for this example that, on the whole, site I is safer than site II.

The analysis can be refined if the probable spill location is taken into account. Spills occurring along a waterway will cause immediate pollution, while those occurring inland will not. Inland spills can be broken down into those occurring in highly populated areas, where the sewer system will funnel a spill into water very quickly, and those occurring in rural areas, where the spill reaches water through a relatively slow leaching process. As a first approximation one can include the effect of these factors by assuming that sewer line density is directly proportional to population density and that the time that a spill takes to get to water is inversely proportional to the sewer density.

ACCEPTABLE POLLUTION RISK

As mentioned in Part 2, no yardstick was found in the literature that could be used to gauge the level of pollution that society is willing to accept. We considered several possibilities such as converting pollution risk level to a potential human fatality/person-hour exposure and comparing this number with 10^{-9} fatality/person-hour exposure as suggested by Starr[1,2] or estimating the percentage of the total water shed along the route of transport that could potentially be polluted and comparing that value with some acceptable level such as 0.1% per year, or estimating the cost of recovering or cleaning the polluted water and comparing this cost with the total cost of disposal or the cost that society pays for clean water. Such schemes suffered from either a lack of data or the difficulty in arriving at or estimating certain parameters. The most promising approach appeared to be that which we described in Part 2 in which the quantity of the waste that society normally voids into its waters from manufactured consumer products is used as an acceptability yardstick. The data needed to arrive at this yardstick will be available shortly.[13] For the present, however, the absolute volume of water that could potentially be polluted every year due to accidents will have to be used only to compare two or more disposal sites away from the source or to compare different modes of transportation.

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APPENDIX E

ANALYSIS OF FEDERAL AND STATE LAWS

FEDERAL LEGISLATION AND STATUTES

We analyzed the structures of Federal legislation and statutes relating to hazardous wastes as of September 1972 (Table E.1). We have also indicated those offices within the Executive Branch (Figure E.1 and Table E.2) and within the Congress (Table E.3) that might have an interest in or control over hazardous wastes.

The Federal statutes that we identified as being of interest to this case are as follows:

1. Federal Water Pollution Control Act
2. Rivers and Harbors Act of 1899
3. The Solid Waste Disposal Act
4. Air Pollution Prevention and Control Act
5. National Environmental Policy Act
6. Carriage of Explosives or Dangerous Substances
7. Federal Insecticide, Fungicide, and Rodenticide Act
8. Food, Drug, and Cosmetic Act
9. Hazardous Substances Act
10. Department of Transportation Act
11. Community Facilities and Advance Land Acquisitions
12. Public Works and Economic Development
13. Explosives and Other Dangerous Articles
14. National Wilderness Preservation System
15. Marine Resources and Engineering Development
16. Atomic Energy Act
17. Proposed Toxic Substances Control Act of 1972.

Of these 17, the first 10 seek to cope directly with problems in the environment or to people and thus are of particular interest.

The categories of information which we included in Table E.1 are described below. The table is not meant to be a lawyer's analysis, but merely a convenient device for presenting to a variety of users those characteristics of Federal statutes important to this research effort. However, the table maps the topography of Federal legislation and paves the way for more detailed examination of legal language and regulation as the need arises.

For each statute the following information is included: (1) the formal title, (2) the common name (or Short Title), and (3) the reference information for locating the statute in the U.S. Code Annotated. In many instances each amendment to a statute has a common name; this name is also included for reference.

For emphasis, statements considered to be particularly relevant are underlined or boxed within each of the categories. Some subjective comments gleaned from various books and papers are referenced in parentheses.

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LAW:

Listed here are the one or several means of identifying a statute, beginning with the most general and descriptive title. For example, "Pollution Control of Navigable Waters" is the title of that chapter on the U.S. Code Annotated, the number of which is cited, which includes a series of Federal laws described by the title specified in legislation.

PURPOSE:

We summarize what is usually set forth in the "Declaration of Purpose" clause beginning each statute, but in some cases include our own interpretation of the major thrust of the statute.

EXECUTIVE AGENCY RESPONSIBLE/NATURE OF POWERS:

Listed here is the executive agency responsible now. In many cases this differs from the agency designated by Congress originally, because offices formerly in, for example, the Department of the Interior were reassigned to the Environmental Protection Agency when it was created.

This entry also shows various types of administrative and legal powers assigned to the agency by the statute. We have used four categories:

- Adjudicatory: having quasi-judicial powers, including the right to hold hearings;
- Promotional: having the power to promote the purposes of the statute, typically by means of financial aid and Federal administrative support;
- Rule-making: having power to set standards and rules within guidelines set by Congress; and
- Advisory: having authority only to suggest and recommend actions, and to carry out research and development activities which may or may not lead to action by other Federal agencies or state and local government bodies.

TYPES OF HAZARDOUS SUBSTANCES:

Here we summarize the categories of substances covered by the statute. Clearly, many "substances" of concern to legislatures in the past are not "hazardous wastes" within the meaning of this research effort. Presently, some "wastes" are components of "substances." One legislative task resulting from this search may be to amend present statutes, to make them apply more specifically to "hazardous wastes."

BASIC CONTROL STRATEGY:

This column lists our summary of how the authors of each statute sought to control the refuse or hazardous substance. The spectrum ranges from none to stringent: from mere research efforts to setting of standards (more or less restrictive), to firm central control, as in the case of radioactive wastes. The strategy of control reflects Congress's theory at the time of enactment about (1) what the problem is, and (2) what the federal government can and should do about the problem.

TECHNIQUES:

This column lists the specific means by which the control strategy is to be effected, such as making matching grants, requiring permits, and establishing standards.

ENFORCEMENT POWERS:

This column outlines the provisions for assuring compliance with the statute. Statutory standards may be enforced either through administrative action or by bringing an action in a court of law or equity. Among the variety of enforcement techniques that an agency might employ are the following:

- Seek an injunction in court to halt the prohibited acts.
- Assess fines for violation (hopefully acts as deterrent).
- Impose criminal sanctions for violation.
- Issue cease and desist orders.
- Deny or withhold permits.

STRENGTHS AND WEAKNESSES:

These two columns list assessments by various analysts, including ourselves, summarizing experience to date.

AMENDMENTS PENDING:

In a few cases, bills now pending before Congress could, if enacted, significantly modify the statutes now on the books, and are therefore important to our thinking. For example, one section of the "Water Quality Improvement Act of 1970," which is now Section 1162 of the U.S. Code, requires the President, using the EPA, to draw up and publish a list of "hazardous substances" and how to control them; he has, accordingly, proposed the "Toxic Substances Control Act of 1972," now pending as a bill before the House of Representatives.

EFFECTIVENESS TO DATE:

In this column we report such summary judgment as we have obtained as to how the statutes have been applied in practice.

APPLICATIONS TO STATE AND LOCAL GOVERNMENTS:

Information in this column has great administrative and legal importance, concerning both the Federal structure of American government and the questions before this case. The extent to which Congress will reserve to the Federal government powers to enforce decisions in all legal jurisdiction will critically influence how effectively wastes can be disposed.

TABLE E.1

FEDERAL LAWS RELATING TO HAZARDOUS WASTES

TABLE E.1 (Continued)

Federal Laws Relating to Hazardous Wastes

1.a. Pollution Control of Navigable Waters: 33 USC 1151-1175*

Purpose	Exec. Agency Resp. Nature of Powers	Types of Hazardous Subs.	Basic Control Strategy	Techniques
To enhance the quality and value of our water resources and to establish a national policy for the prevention, control and abatement of water pollution.	EPA Ajudicatory (e.g., quasi-judicial powers, including the right to hold hearings). Promotional (e.g., power to promote purpose through financial aid). Rule Making (in certain circumstances) Advisory (e.g., carry out research & development activities). ATTORNEY GENERAL When referred by EPA for court action.	Sewage discharges into any waters. Pollution in interstate waters and parts thereof.	1. Federal government stimulates & funds Planning, Investigation, and Research. 2. Relies on States to establish & enforce standards. Federal EPA to set standards only after states fail to do so, except in interstate cases.	Make joint investigations with any Federal agencies, with State water pollution control agencies & interstate agencies and the Municipalities & industries of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substance which may adversely affect such waters. Make grants not to exceed 50% of administrative expenses of a planning agency for a period not to exceed 3 years to develop an effective, comprehensive water quality control & abatement plan for a basin. Carry out research, investigations, experiment demonstrations, & studies alone & in cooperation with public authorities, agencies & institutions and private agencies & individuals. Make grants for research and development not to exceed 75% of costs. Require states to establish standards for all interstate & coastal waters.

*Common mane(s): "Federal Water Pollution Control Act"
"Water Quality Act of 1965"
"Water Quality Improvement Act of 1970"
"Clear Water Restoration Act of 1966"

Amendments: Amendments of 1956 – Amendments of 1961

Note: The Amendments of 1972, a major revision of these statutes are analyzed in Table E.1.b.

Ref. to U.S. Code: (incorporates 33 USC 466 et seq)

TABLE E.1 (Continued)

Enforcement Powers	Strengths	Weaknesses	Amendment Pending	Effectiveness to Date	Applications to State & Local
Three step process: 1. Convening conference to secure action through negotiation.	Fast action in case of violation of water quality standards. (Toxic Subs)	May be used only after pollution has occurred and then, difficult to relate change in water quality to a specific discharge. (GAO)	Administrator urging legislation to provide him with less time consuming procedures by eliminating public hearing step. (Lewin)	Since 1970 Federal enforcement actions have become more frequent & stronger. (GAO)	Recognizes, preserves rights of states in preventing & controlling water pollution.
2. Public hearing to receive testimony.	Demonstrates Federal concern about pollution.	Federal authority limited at conference since (a) no direct Federal relation with polluters and (b) no subpoena authority. (Lewin)		Only 51 Federal actions taken in a period of 14 years. (Degler)	Depends on state initiative to apply for federal money.
3. Federal court action for non-compliance. If standards violated: 1. 180 days notice to comply. 2. Federal court action.	Initiate enforcement action when States fail to act in cases of interstate pollution.	Depends on state initiative. (Lewin)		States taken advantage of:	Agencies receiving grants are required to draw up & submit plans for EPA approval.
		Underfunded. (Degler)			State guidelines for setting standards included an order that standards would not be acceptable unless they provided for reduction of all existing municipal & industrial pollution within five years. (Degler)
		No authority to enforce specific effluent restrictions which would permit the setting of treatment requirements for plants, before pollution became a problem. (GAO)		In many cases when conf. recommendations were not followed, conferences were reconvened & dates for compliance extended. (GAO)	
		Conference & hearing formalities very slow. (GAO, Toxic Subs & Lewin)			
		Federal Government precluded from playing a fully effective role because of the requirement that the Federal enforcement assistance must be requested by the state if only that state is affected. (Lewin)			
		Vested interests generally stronger at state than Federal level. Probably unopposed at most local levels. States weaker in money & competence than Federal government. (RT)			

TABLE E.1 (Continued)

1.b. Federal Water Pollution Control Act Amendments of 1972

Purpose	Agency & Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques	Enforcement Powers
To achieve wherever possible by July 1, 1983 water clean enough for swimming and other recreational uses and clean enough for protection and propagation of fish, shell-fish and wildlife	EPA Rule-making	Pollutants	States retain primary responsibility to prevent, reduce and eliminate water pollution, but within a national program framework of specific actions	Set specific dates for industrial & municipal discharges to be treated & set level of treatment New grant program with stringent regulations Expand water quality standards program Require intrastate standards to be set by states by April 1973 Require states to hold public hearings every 3 years to review standards and up-date New system of permits replacing 1899 Refuse Act	Court injunction when imminent danger Take action when states do not or cannot Federal Aid Permits Inspection Fine Imprisonment
		Hazardous Substances-defined as substances presenting an imminent and substantial danger to public health or welfare, including fish, shell-fish, wildlife, shorelines and beaches		Extends oil pollution control, liability & enforcement provisions to hazardous substances (maybe 33 usc 116x)	

TABLE E.1 (Continued)

Strengths	Weaknesses	Amend	Effective	Application to State and Local
Extends control to all U.S. waters, not just interstate Strengths control over toxic pollutants Allows for citizens or groups to sue to enforce non-discretionary actions of administrator, effluent standards or orders of administrator - limited to persons having an "interest" Urges international effluent standard agreements Small Business Admin. loans provided for	Except for permits and grants for municipal waste treatment construction, exempts EPA from NEPA under this bill	May be amended to not exclude EPA from NEPA	N/A	State issued permits subject to Federal veto States may adopt more stringent regulations In order to apply for permit, must obtain State certification If certification by one state results in a discharge not in compliance with standards in another, permit not granted

TABLE E.1 (Continued)

2. Rivers & Harbors Act of 1899*

Purpose	Exec. Agency Resp. Nature of Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques
Prevent the creation of any obstruction to the navigable capacity of any U.S. waters.	EPA Rule Making Army Corps of Engineers Rule Making	Any refuse matter, other than that flowing from streets and sewers, in navigable waters.	Monitor & limit amounts discharged into waterways.	All waste dischargers required to apply for permits; permits issued by Corps of Engineers after review & Approval by EPA.

*Common name(s): The Refuse Act of 1899.

Ref. to U.S. Code: 33USC 403 et seq.

TABLE E.1 (Continued)

Enforcement Powers	Strength	Weaknesses	Amendments Pending	Effectiveness to Date	Applications to State & Local
Violation results in fine of $500-2500 and/or 30 days-1 year imprisonment. Prosecution of offenders by U.S. attorneys when requested by Secretary of Army or any designated officials.	Violations can be referred to the Department of Justice for court action without delay. (GAO) Because of broad judicial interpretation, provides valuable enforcement tool by extending Federal authority to intermittent discharges of waste into navigable waters. (Lewin) Provides for immediate court action. (Toxic Subs) Through coordination with Federal Water Pollution Control Act can extend authority to intrastate waters where no Federal Water Quality Standards apply, as well as to interstate waters. (Lewin) Violators can be convicted even if pollution complies with water quality standards. (Lewin) Application for permits must include data on composition and volume of wastes, precludes hiding information on the grounds of "industrial secrets."	Does not cover municipal liquid sewage and therefore does not cover industrial wastes going into municipal sewers. (GAO) Enforcement authority split between EPA and Corps. (Toxic Subs) Policy changed by memo from Department of Justice (6/70) directing U.S. Attorneys to use in charges of non-continuous nature: 1. emergencies, 2. if so requested by Corps. Continuous polluters fall under jurisdiction of FWQ Administration. If liberal in defining "emergencies" this may not limit Act. (Lewin)		Few permits issued prior to April 1971. Registration required for 41,000 industrial sources of pollutants by mid 1971.	To obtain a permit company must obtain state certification that it will be in compliance with standards. Enforcement powers tend to subjugate role of states. (Toxic Subs)

TABLE E.1 (Continued)

PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
To support a National Research & Development Program for new and improved methods of solid waste disposal. To provide technical & financial assistance to state, local, and interstate agencies. Amended to also promote recycling, local planning and training.	EPA Promotional Advisory	Solid wastes defined as: Garbage, refuse & other discarded solid materials including solid waste materials resulting from industrial, commercial, agricultural operations, community activities, but does not include solids or dissolved material in domestic sewage, silt, dissolved or suspended solids in industrial effluents, or other common water pollutants.	Initiate programs of research & training, looking toward design and implementation of national disposal system.	Grants Find ways of disposal without creating health hazards or pollution. Recycle scrap materials into production process. Submit to Congress by 10/26/72, comprehensive report & plan for the creation of a system of National disposal sites for the storage & disposal of hazardous wastes which may endanger public health or welfare.

*Includes: Resource Recovery Act of 1970 and National Materials Policy Act of 1970

Ref. to U.S. Code: *Includes: Resource Recovery Act of 1970 and National Materials Policy Act of 1970 42 USC 3251-3259

6. Air Pollution Prevention & Control*

PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
To protect the quality of the Nation's air resources.	EPA Promotional Rule Making Ajudicatory Advisory	5 air pollutants specified: Sulfur Oxides Particulates Carbon Monoxide Oxidants Hydrocarbons States regulate all other air pollutants until Federal decides to step in.	Research Set standards for designated air pollutants. Abatement procedures. State set standards for ambient air quality and those pollutants not specified by Federal standards. Financial Assistance i.e. for research, investigation experiment, training, survey, study causes, effects, extent, prevention & control of air pollution.	Abatement (interstate & when requested intrastate). After the fact. 1. Conference 2. Hearing 3. Court action 180 day notice procedure for violation of standards. Motor Vehicles Regulation of emissions Standards Federal standards on Sulfur Oxides Particulates Carbon Monoxide Oxidants Hydrocarbons State sets others States have three years to comply with standards.
To control automotive air pollution.		Auto emissions.	Set Federal emission standards. Register fuel additives. Research & grant programs.	Regulate crankcase & exhaust emissions for gasoline-powered vehicles. Require registration of fuel additives.

Common Name(s): ''Clean Air Act'' (1963) - ''Air Quality Act of 1967''

Amendments: ''Clean Air Amendments of 1970''

Ref. to U.S. Code: 42 USC 1857 et seq.

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENT PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
	Provides for up to 2/3 cost of local projects and 3/4 cost of regional projects. (Degler)	No enforcement powers. Only research.				
$25,000/day and/or 1 year in jail for knowingly violating and first offense. Second-time violators are subject to twice that amount. If state violates—30 day notice, then EPA takes over administration of state plan.	Act forbids Federal agencies to do business with convicted air polluters until situation corrected. (Degler) Strong fuel additive provisions. Authorizes administrator to seek court injunction immediately if pollution presents a substantial danger to health.	No timetable for developing national ambient air quality goals.		Very little before 1970.	States may set more stringent standards than Federal.	
		States being given extensions.				
Fines					Federal preemption of State's right to set standards on automobile exhaust emissions. (except when state already adopted e.g. California.)	

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENT PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
No Federal money legislation or major actions granted without impact statement.	*Prior* analysis of effects. Very strong statement of committment to environmental priorities.	There are major controversies surrounding the meaning & effect of this act. (Degler)		Numerous law suits have been brought under the act. (Degler)		
Fine $2000 for each violation. Seizure of vessel. If death or injury occur as a result of non-compliance fine is $10,000 and/or imprisonment for maximum of 10 years.						Does not apply to pleasure vessels. Inflammable liquid, cargo in bulk-provided the bulk . Cargo shall be subject to 46 USC 391a: (Coast Guard shall regulate design of bulk liquid cargo ships to ensure safety of life & property; perform inspections and issue permits to enforce regulations), Armed Forces.
Fines of $500 to $10,000 and imprisonment of 1 year to 3 years. Seizure of product.		No control over application of substances. (Toxic Subs)	Comprehensive Insecticides Bill pending (Toxic Subs)			

TABLE E.1 (Continued)

	LAW	PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
5.	Declaration of National Environmental Policy.	To declare a National policy encouraging harmony between man & his environment. To establish the Presidents council on Environmental Quality.			a) Require thought and analysis about potential damage before acting. b) Federal authority for certifying major projects.	1. Establish as a national policy the use of all practible means to create a healthful environment. 2. Require environmental impact statement before construction of projects. 3. Council on EQ is information gathering body, review of current programs, develop national policy, research.
	Common Name(s): ''National Environmental Policy Act.'' (1969)					
	Ref. to U.S. Code: ''National Environmental Policy Act.'' (1969)					
6.	Carriage of Explosives or Dangerous Substances	To limit hazards to health & property, created by explosives or other dangerous articles or substances.	DOT Rule Making	Detonating compounds High explosives Other dangerous articles or substances e.g. Inflammable liquids Inflammable solids Oxidizing materials Corrosive liquids Compressed gases Poisonous articles or substances Hazardous articles	Set regulations.	Regulations to define, describe, name & classify all dangerous articles or substances; and make other regulations such as packing, marking, labeling, apply to interstate or foreign commerce by water.
	Ref. to U.S. Code: 46 USC 170-179 (1940) Derived from Act of 1871					
7.	Federal Insecticide, Fungicide & Rodenticide Act	To ban the sales & shipment of unregistered economic poisons.	EPA Rule Making	Economic poisons: insecticide rodenticide fungicide nematocide repellents defoliants dessicants household disinfectants	Register & control economic poisons by Federal authorities before enter commerce.	Registration Regulations pertaining to packaging, labelling, coloring, adulteration.
	Ref. of U.S. Code: 7 USC 135-135k (1947)					

TABLE E.1 (Continued)

LAW	PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
8. Food Drug & Cosmetic Act	To prohibit the sale or manufacture of adulterated or misbranded food,drug, or cosmetic.	HEW Rule Making	Adulterated or misbranded Food Drug Cosmetic	Set standards Require registration	Issue injunctions, restraining orders or seizure order when Secretary has probable cause to believe an article is dangerous to health.
Ref. to U.S. Code: 21 USC 331-381 (1938)					
9. Hazardous Substances	Protection of the public health & safety in view of the special hazard presented by hazardous substances.	HEW Rule Making	Toxic Substances Corrosive Substances Irritant Substances Sensitizers Substances Flammable Substances Pressure Generating Substances (through decomposition). Toys presenting electrical mechanical or thermal hazards.	Labelling Regulations	Prohibit introduction into interstate commerce of any misbranded or banned hazardous substance. Prohibit alteration or removal of label. Establish label requirements by regulation. Direct that records be kept of the movement in interstate commerce of any hazardous substances.
Common Name(s): (Child Protection & Toy Safety Act of 1969)					
Ref. to U.S. Code: 15 USC 1261-1273 (1960)					
10. Department of Transportation	To develop a National transportation policy. To create the Department of Transportation. State a transportation policy applicable to hazardous substances.	DOT Promotional Advisory DOT Office of Hazardous Material.	Hazardous Substances as defined in 49 CFR 172 in transit.	Develop, collect, & disseminate information relevant to domestic and international transportation. Research & development relating to transportation.	Report to President & Congress on studies and legislative recommendations yearly (including recommendations regarding hazardous substances.) Conduct research & development and help with local planning. Grants for local planning.
Ref. to U.S. Code: 49 USC 1651 et seq.					

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENTS PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
Fine of $1000 and/or 1 year imprisonment. OR, if already being prosecuted under this section and convicted of another violation then $10,000 and/or 3 years imprisonment. OR, if committed with intent to defraud or mislead, then $10,000 and/or 3 years imprisonment.						Exemption from penalties in certain cases of "good faith"
Fines Seizure	This is a first step in preparing the public and industry for the need for control of hazardous substances.	Hard to enforce, injured party must bring suit. No testing of substances or toys beforehand.			Only applies to interstate commerce.	Does not apply to hazardous substances such as economic poisons nor to food, drugs & cosmetics nor to fuels. (covered by other statutes such as FIFRA & FD&C Act.)
	Federal agency exists with capacity to coordinate transportation aspects of disposal methods.				Only applies to interstate commerce. Financial aid for research & development & planning.	

TABLE E.1 (Continued)

LAW	PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
11. Community Facilities and Advance Land Acquisitions	To make grants to local public bodies & agencies to finance specific projects for basic water facilities & for basic sewer facilities.	EPA Promotional	Municipal Wastes.	Financial Aid.	Financial aid to promote construction of basic water & sewer facilities.
Ref. to U.S. Code: 42 USC 3102 (1965)					
12. Public Works & Economic Development	To provide for sewer & other waste disposal facilities.	EPA Promotional	Untreated wastes.	Certification of plans.	Certification of facilities to be constructed, such that any waste material carried will be adequately treated before discharged into public waterway.
Ref. to U.S. Code: 42 USC 3136 (1965)					
13. Explosives and other Dangerous Articles.	Formulate regulations for the safe interstate and foreign transport of explosives and other dangerous articles.	Department of Transportation Rule Making Ajudicatory	Explosives Dangerous articles including: Radioactive materials, etiologic agents, flammable liquids, flammable solids, oxidizing materials, corrosive liquids, compressed gases, poisonous substances.	Set regulations.	Regulations based on the best known practicable means for securing safety in transit on both land & water. Regulations take effect 90 days after formulation.
Ref. to U.S. Code: 18 USC 834,835 (1948)					

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENTS PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
The grant will not be made unless the Secretary of Interior certifies that any waste material carried by facilities all be adequatly treated.						Amount of grant will not exceed 30% of development cost except where population is less than 10,000, it may be 90%.
Witholding of financial assistance.						
Fine of $1,000 and/or one year in prison. If death or bodily injury results, fine $10,000 and/or 10 years imprisonment.				Court case citations showing this Act invoked in cases of interstate transportation of "obnoxious waste materials.	Does not invalidate state statutes.	

TABLE E.1 (Continued)

LAW	PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
14. National Wilderness Preservation System	To establish a National Wilderness Preservation System composed of federally owned areas.	Department of Agriculture Advisory Department of Interior Advisory		Declare and set aside wilderness areas.	Review of existing federally owned lands. Acquisition of additional land within the perimeter of a designated wilderness area.
Common Name(s): ''Wilderness Act of 1964''					
Ref. to U.S. Code: 16 USC 1131-1136 (1964)					
15. Marine Resources & Engineering Development	To develop a long-range National program in marine science. To establish the National Council on Marine Resources & Engineering Development.	Office of President Advisory Promotional		Investigation & study.	Investigate & study all aspects of marine science and recommend an overall plan for a National program.
Ref. to U.S. Code: 33 USC 1101-1108 (1966)					
16. Development & Control of Atomic Energy	To develop, control and use atomic energy for the benefit of mankind. note: Because of the peculiar nature of atomic energy i.e. extremely hazardous, this act places total control in the hands of an independent Federal agency to expedite control of this dangerous substance.	AEC Total Control	Atomic energy	Strict Federal control of all aspects of atomic energy.	Establish Atomic energy commission. Set standards for possession use & disposal of atomic energy. Study and investigate the nature of atomic energy and its applications.
Common Name(s): ''Atomic Energy Act of 1954''					
Ref. to U.S. Code: 42 USC 2011-2296 (1954)					

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENTS PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
	Shows Federal concern for the preservation of wilderness areas for future generations.	Allows mining operations to go on in designated wilderness areas. But those mining locations may be used solely for mining or processing operations. Allows for the President to authorize specific wilderness areas development for "facilities needed in the public interest..."				
	Planning for a National program. Could have provided important resource if information regarding ocean dumping of hazardous materials.	Because of lack of funds Council expired June 30, 1971.				
Issue licenses. FBI investigations. Fines & imprisonment.	Very strong centralized control of an extremely hazardous substance.				Pre-empts state control but allows for cooperation with states regarding byproducts & source material, and recognizes the eventual improvement of state capabilities & therefore the eventual legislative changes necessary to give states the right to some control.	

TABLE E.1 (Continued)

LAW	PURPOSE	EXEC. AGENCY RESP. NATURE OF POWERS	TYPES OF HAZARDOUS SUBSTANCES	BASIC CONTROL STRATEGY	TECHNIQUES
17. Proposed Toxic Substances Control Act*	To require premarket testing of new chemical substances, and to regulate use & distribution of chemical substances.	EPA	Chemical substance defined as any organic or inorganic substance of a particular molecular identity, or any uncombined chemical radical or element.	Premarket testing	Issue regulations for test protocols for various classes and uses of chemical substances.
		Rule Making		Regulations on use & distribution.	Issue regulations pertaining to existing chemical substances, manufacture, processing, use & disposal.
	To establish the Chemical Substances Board.	Ajudicatory		Research	Conduct research and monitoring to determine, among other things, the proper test protocols.
				Inspection of manufacturers.	Carry out inspection of manufacturers.
	To protect the navigable waters from harm resulting from the transportation of hazardous chemical substances.	Coast Guard		Regulate the transportation.	Establish vessel traffic services & systems for ports, harbors & other waters. Develop inspection procedures.

*S 1478 passed Senate referred to the House of Representatives Committee on Interstate & Foreign Commerce. 6/1/72.

TABLE E.1 (Continued)

ENFORCEMENT POWERS	STRENGTH	WEAKNESSES	AMENDMENT PENDING	EFFECTIVENESS TO DATE	APPLICATIONS TO STATE & LOCAL	RESTRICTIONS OR EXEMPTIONS
1. Two step process: Hearings Directives 2. If imminent hazard exists, substance may be seized. 3. Fines	Offers very strict guidelines on all aspects of manufacture & use. Applies to everything even those included under FIFRA, Food, Drug & Cosmetic Act, AEC, and the transportation of such as regulated by DOT.	Overland transportation regulated by existing CFR under DOT.			States may not impose regulations after EPA has set them for specific substances except to ban the substance entirely. States may regulate all other chemical substances.	
Fines	Subpena authority granted.	Apparently less concern for transportation over land.				Does not apply to the St. Lawrence Seaway or the Panama Canal.

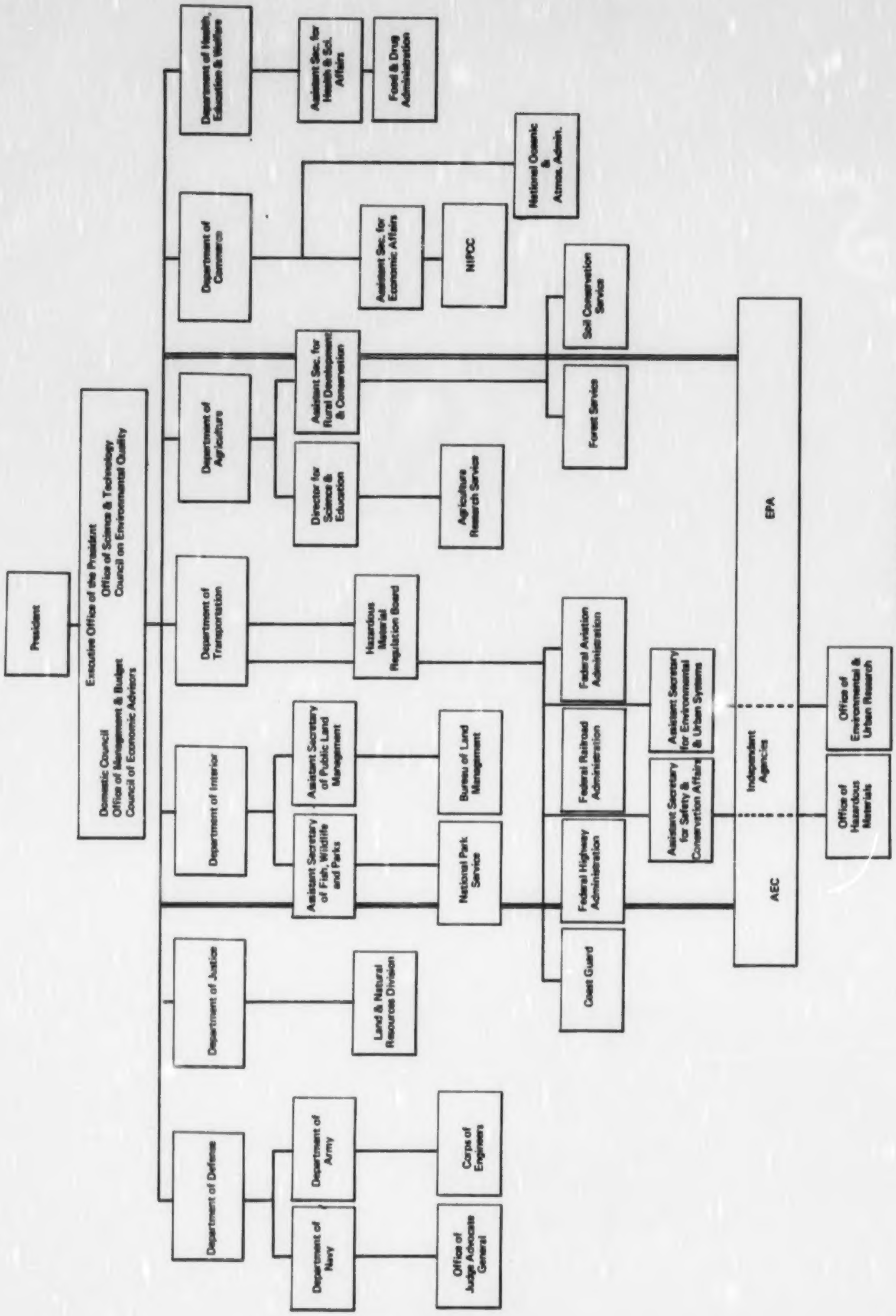
President
Executive Office of the President
Domestic Council
Office of Management & Budget
Council of Economic Advisors
Office of Science & Technology
Council on Environmental Quality
Department of Defense
Department of Justice
Department of Interior
Department of Transportation
Department of Agriculture
Department of Commerce
Department of Health, Education & Welfare
Department of Navy
Department of Army
Land & Natural Resources Division
Assistant Secretary of Fish, Wildlife and Parks
Assistant Secretary of Public Land Management
Hazardous Material Regulation Board
Director for Science & Education
Assistant Sec. for Rural Development & Conservation
Assistant Sec. for Economic Affairs
Assistant Sec. for Health & Sci. Affairs
Office of Judge Advocate General
Corps of Engineers
National Park Service
Bureau of Land Management
Agriculture Research Service
NIPCC
Food & Drug Administration
National Oceanic & Atmos. Admin.
Coast Guard
Federal Highway Administration
Federal Railroad Administration
Federal Aviation Administration
Forest Service
Soil Conservation Service
Assistant Secretary for Safety & Conservation Affairs
Assistant Secretary for Environmental & Urban Systems
AEC
Independent Agencies
EPA
Office of Hazardous Materials
Office of Environmental & Urban Research

FIGURE E.1 ORGANIZATIONAL UNITS WITHIN FEDERAL EXECUTIVE BRANCH THAT HAVE INTEREST IN HAZARDOUS WASTES

TABLE E.2

ORGANIZATIONAL UNITS IN FEDERAL EXECUTIVE BRANCH WITH INTEREST IN HAZARDOUS WASTES

EXECUTIVE OFFICE OF THE PRESIDENT

Domestic Council

Formulates and coordinates domestic policy recommendations. Involved in policy decisions relevant to hazardous wastes.

Office of Management and Budget

Assist President in formulation of fiscal program of the government. Assist President by clearing and coordinating departmental. Advise on proposed legislation, recommending Presidential action on legislative enactments. Assist President in the consideration and clearance of executive orders.
Involved in allocating budget and recommendations involving legislation for hazardous waste programs.

Council of Economic Advisors

Analyzes national economy and advises on economic developments. Involved in economic policy decisions that would indirectly relate to hazardous waste programs.

Office of Science and Technology

Evaluates major policies, plans and programs of science and technology of various agencies of Federal government. Potentially involved in the scientific assessment of the selection of national disposal sites for hazardous wastes.

Council on Environmental Quality

Established by NEPA to formulate national policies to promote the improvement of the quality of the environment. Potentially involved in the evaluation of the national disposal sites' impact on the environment.

DEPARTMENT OF DEFENSE

Department of the Navy

Office of the Judge Advocate General

Provides advice and information on legal aspects of international relations, including ... law of the sea and of the sea beds, including marine pollution. Would be involved in any legal ramifications of ocean dumping of hazardous wastes.

TABLE E.2 (continued)

Department of the Army

Corps of Engineers

Administers laws for the protection of navigable waterways.
Potentially involved in the administration of procedures involving transportation, treatment and disposal of hazardous wastes.

DEPARTMENT OF JUSTICE

Land and Natural Resources Division

The Assistant Attorney General in charge of this division supervises all suits and matters of a civil nature in the courts relating to real property, including lands, water, other related natural resources, the Outer Continental Shelf, marine resources, the protection of the environment. Among other functions of the division are the review of legislative proposals affecting matters within the scope of its litigation responsibilities.
Would be involved in all legal aspects of the disposal of hazardous wastes, and the review of any proposed legislation covering hazardous wastes.

DEPARTMENT OF THE INTERIOR

Assistant Secretary for Fish, Wildlife & Parks

National Park Service

Assistant Secretary for Public Land Management

Bureau of Land Management

Both offices are involved in the administration of the Wilderness Preservation Act.
Would be potentially involved in the decision of where to locate the national disposal sites.

TABLE E.2 (Continued)

DEPARTMENT OF TRANSPORTATION

Coast Guard

Cooperates with other agencies in their law enforcement responsibilities, enforces conservation laws, is overseer of safety in shipping on inland and coastal waterways. Involved in the safe transport of hazardous wastes by water.

Federal Highway Administration

Concerned with the total operation and environment of the highway systems, with particular emphasis on improvement of highway oriented aspects of safety.
Directly involved in the safe transport of hazardous wastes on highways.

Federal Railroad Administration

Support rail transportation, research and development to improve rail and ground transportation.
Directly involved in the safe transport of hazardous wastes by rail.

Federal Aviation Administration

Regulates air commerce to promote its safety and development.
Directly involved in the safe transport of hazardous wastes by air.

Assistant Secretary for Safety and Conservation Affairs

Office of Hazardous Materials

Develops and coordinates programs for the regulation of hazardous material.

Assistant Secretary for Environmental and Urban Systems

Office of Environmental and Urban Research

Responsible for environmental and overall urban transportation needs, goals and policies; and innovative approaches to urban transportation and environmental enhancement programs.
Involved in transportation aspects of hazardous wastes in urban areas.

TABLE E.2 (Continued)

DEPARTMENT OF AGRICULTURE

Director for Science and Education

Agricultural Research Service

Improve crop and livestock yield and strains.
Potentially involved in anything detrimental to that end.

Assistant Secretary for Rural Development and Conservation

Forest Service

Administer national forests.
Potentially involved in disposal site selection.

Soil Conservation Service

Directed to effectively utilize the productive capacity of soil and water resources with concern for problems of pollution and preservation of these resources.
Potentially involved in disposal of hazardous wastes with regard to soil pollution.

DEPARTMENT OF COMMERCE

Assistant Secretary for Economic Affairs

National Industrial Pollution Control Council (NIPCC)

Defines and reports potential control problem areas within industry.
Would be concerned with hazardous wastes pollution from industry.

National Oceanic and Atmospheric Administration

Explore, map and chart the global oceans and assess the seas' potential yield to the nation. To manage, use and conserve these animal and mineral resources; to warn against impending environmental hazard.
Involved in the handling of hazardous wastes so as to protect the oceans.

DEPARTMENT OF HEALTH, EDUCATION AND WELFARE

Food and Drug Administration

Protects the public health of the nation by insuring that foods, drugs and cosmetics are safe, pure and properly labelled.
Would be concerned with chemical substances being classified as hazardous. May also be consulted on provisions for model law.

TABLE E.2 (Continued)

INDEPENDENT AGENCIES

Atomic Energy Commission

To provide that the development, use and control of atomic energy will be directed to make the maximum contribution to the general welfare.
Because of the peculiar nature of atomic energy, i.e., extremely hazardous, this agency has been delegated total power with regard to the various aspects of dealing with atomic energy. It may therefore serve as a model agency for one to deal with hazardous substances in general.

Environmental Protection Agency

Created to permit coordinated and effective governmental action to assure the protection of the environment by abating and controlling pollution on a systematic basis.
Would have overall responsibility for the administration of any program dealing with the disposal of hazardous wastes.

TABLE E.3

Structural Units in Congress with Interest in Hazardous Wastes

JOINT COMMITTEES

- Joint Committee on Atomic Energy
  - Subcommittee on Legislation

SENATE

- Committee on Agriculture and Forestry
  - Subcommittee on Soil Conservation and Forestry
  - Subcommittee on Watershed Projects
- Committee on Commerce
  - Subcommittee on Energy, Natural Resources and the Environment
  - Subcommittee on the Merchant Marine
  - Subcommittee on Surface Transportation
- Committee on Banking and Currency
- Committee on the Interior and Insular Affairs
  - Subcommittee on Parks and Recreation
  - Subcommittee on Public Lands
  - Subcommittee on Water and Power Resources
- Committee on Public Works
  - Subcommittee on Air and Water Pollution
- Committee on Appropriations
  - Subcommittee on Agriculture and Related Agencies
  - Subcommittee on Department of Interior and Related Agencies
  - Subcommittee on Department of Labor, Health, Education, Welfare and Related Agencies
  - Subcommittee on Public Works
  - Subcommittee on Transportation

TABLE E.3 (Continued)

HOUSE OF REPRESENTATIVES

- Committee on Government Operations
    - Subcommittee on Conservation and Natural Resources
- Committee on Interior and Insular Affairs
    - Subcommittee on Mines and Mining
    - Subcommittee on National Parks and Recreation
    - Subcommittee on Public Lands
- Committee on Interstate and Foreign Commerce
    - Subcommittee on Transportation and Aeronautics
- Committee on Ways and Means
- Committee on Merchant Marine and Fisheries
    - Subcommittee on Coast Guard, Coast and Geodetic Survey, and Navigation
    - Subcommittee on Oceanography
- Committee on Public Works
    - Subcommittee on Rivers and Harbors
    - Subcommittee on Watershed Development
- Committee on Approriations
    - Subcommittee on Agriculture
    - Subcommittee on Interior and Related Agencies
    - Subcommittee on Labor, Health, Education and Welfare
    - Subcommittee on Public Works
    - Subcommittee on Transportation

NEW JERSEY LAWS AND REGULATIONS RELATING TO HAZARDOUS WASTES

Existing Laws (Table E.4)

New Jersey Department of Environmental Protection Act of 1970. The New Jersey Department of Environmental Protection was established pursuant to reorganization legislation (Chapter 33, P.L. 1970) enacted in 1970. The law amends existing statutes to transfer various pollution control responsibilities from the State Department of Health and other agencies to a new Department of Environmental Protection.

The 1970 law did not repeal or change any provisions of existing air and water pollution statutes except insofar as the names of state agencies were changed. The act authorizes the new department to undertake a fairly broad range of administrative techniques to control pollution and to engage in various promotional and planning activities relating to environmental control.

New Jersey Water Quality Improvement Act of 1971. The New Jersey Water Quality Improvement Act of 1971 (Chapter 173, P.L. 1971) confers upon the Department of Environmental Protection the power to deal with damage caused by the unlawful discharge of "petroleum products, debris and hazardous substances" into the waters of New Jersey. Section 3 defines petroleum products, debris and hazardous substances very broadly.

Section 4 prohibits the discharge of the defined substances in a manner which "allows flow or run-off into or upon the waters" of New Jersey and the banks or shores of said waters.

Section 5 empowers the Department to undertake the clean-up of the prohibited discharges and hold the violator liable for the cost.

Section 6 provides fines and penalties for failure to notify the Department immediately of prohibited discharges. If the violation continues, each day during which it continues shall constitute an additional, separate and distinct offense.

Section 7 limits the total amount in fines for any one violator to $14 million except where willful negligence or misconduct is present.

Section 8 authorizes the Department to bring a civil action for injunctive relief to prevent violations.

Section 9 states that the provisions of the Act shall not supersede any more stringent local provisions or other state statutes.

New Jersey Ocean Act (Chapter 177, P.L. 1971). The Clean Ocean Act provides for the control of the dumping of waste materials in waters adjacent to New Jersey. The Act empowers the Department of Environmental Protection to promulgate regulations governing the loading and handling of any vessel carrying sewage sludge, industrial wastes and the like for disposal in the ocean, and enables the state to require dumping farther from shore than the 12-mile limit.

Section 5 of the Act specifically provides for the issuance of permits and the charging of fees by the Department.

Section 6 provides for court actions for injunctive relief to prevent or stop violations and fines to be levied against violators.

Pesticide Control Act of 1971 (Chapter 177, P.L. 1971). This Act empowers the Department of Environmental Protection to regulate the sale, labeling, and use of pesticides. Under the provisions of the Act, the Department is authorized to ban or restrict the use of pesticides which are, or tend to be, dangerous to humans, wildlife, or the environment.

The Act also establishes a nine-member pesticide control council as an advisory body to the Department.

Wetlands Act of 1970 (Chapter 272, P.L. 1970). The Wetlands Act provides for the designation by the Commissioner of Environmental Protection of certain coastal wetlands after public hearing. Any dredging, removing, filling or other activity that alters or pollutes such designated coastal wetland areas requires the issuance of a permit by the Department.

Section 1a of the law states the policy underlying the wetlands legislation. The need for protecting and preserving the ecological balance of these areas is stated. Section 1b mandates that the Commissioner, within two years of the effective date of the act, make an inventory and maps of all tidal wetlands within the State.

Section 2 empowers the Commissioner to adopt, amend, modify or repeal orders regulating, restricting of prohibiting dredging, filling, removing or otherwise altering, or polluting, coastal wetlands.

Section 3 requires that with respect to any proposed order pursuant to Section 2 a public hearing be held in the county in which the coastal wetlands to be affected are located.

Section 4 enumerates so-called "regulated activities"; states that no "regulated activity" is to be conducted upon a wetland without a permit; sets out generally the procedures for securing a permit; and provides a statutory standard to be followed by the Commissioner in granting or denying permits.

Sections 5 and 6 state generally the jurisdiction of the courts and judicial remedies available in actions under the Wetlands Act.

Section 9 provides penalties for the violation of the Act or the Commissioner's orders pursuant to the Act.

Industrial Waste Treatment Act of 1972 (Chap. 42, P.L. 1972). This Act empowers the Department of Environmental Protection to establish standards for the pretreatment of industrial wastes. The Department can insist on industrial pretreatment not only because of the composition and quantity of the chemical wastes, but if the particular municipal plant's treatment facilities are deemed inadequate to handle the untreated wastes.

Fines of up to $5,000 per day of violation may be assessed by the Department. Furthermore, under the statute municipalities are empowered to seal off sewer connections to violators.

Other Related Statutes. A number of other New Jersey statutes are not aimed specifically at waste disposal or pollution but impact on the problem.

The Sewerage Authorities Law of 1946 and the Municipal Utilites Authorities Law of 1957 both provide for the establishment of local authorities or special districts to undertake waste treatment activities. Such authorities or special districts are independent and autonomous from municipal and county agencies. The sewerage and waste treatment activities of such authorities are regulated by the Department of Environmental Protection.

- Food and Drug Laws providing for inspection programs which look for, among other things, the presence of waste materials in or near food.

- Air Pollution laws under which the Department of Environmental Protection's Bureau of Air Pollution monitors and regulates the incineration of refuse material by public and private disposal facilities.

- Legislation providing monetary incentive for better waste disposal techniques. This includes provisions for research and development grants. Another statute (Chapter 127, P.L. 1966) provides for the exemption, upon application of waste treatment facility operators, from payment of local property taxes. Such operators must have been properly certified by the Department of Environmental Protection.

Administrative Implementation and Political Realities

In April 1970, New Jersey established the New Jersey Department of Environmental Protection by merging into a single department all New Jersey agencies which relate to the human environment, and installing the department's commissioner as a member of the

Governor's cabinet. The department was organized by grouping from the former Department of Conservation and Economic Development those divisions responsible for parks and forests, fish and game lands, navigation and water control and supply with the Department of Health's Division of Clean Air and Water which had responsibility for water and air pollution, solid waste management, radiation protection, shellfish control and potable water.

With an annual budget of over $40 million and over 1300 full-time employees, New Jersey's Department of Environmental Protection is responsible for the administration of 373,000 acres of publicly-owned land, enforcement of state statutes on the environment and general oversight of New Jersey's ecology. Under the overall direction of a commissioner, the Department has five operating divisions: Water Resources; Environmental Quality; Marine Services; Fish, Game and Shellfisheries; Parks; and Forestry.

The divisions are further divided into bureaus. For our purposes the operating units of prime interest are the Bureau of Water Pollution Control in the Division of Water Resources and the Bureau of Air Pollution Control and Solid Waste Management in the Division of Environmental Quality.

The Bureau of Solid Waste Management regulates sanitary landfills and monitors and regulates the activities of operators, collectors and haulers of solid waste. Collectors and operators of solid waste disposal facilities must register with the Bureau. The Bureau is charged with giving due consideration to the comprehensive solid waste management plan before approving new facilities. An important function of the Bureau is to monitor the operation of disposal sites through inspection programs to assure conformance with applicable regulations and health codes. The Bureau of Solid Waste has the power to force governmental and private entities which engage in solid waste related activities to comply with the statewide comprehensive management plan. A court injunction may be sought in the name of the Commissioner of Environmental Protection.

Another important New Jersey administrative body is the Public Utilities Commission (PUC), which is empowered to regulate the activities of collectors and haulers of solid waste as well as those of operators of disposal facilities. The PUC uses all the traditional tools of state utility regulatory bodies such as the issuance of certificates of public convenience and necessity after hearings, inspection of financial records to assure fitness to operate, rate regulation, and route regulations of haulers.

The Bureau of Water Pollution Control undertakes the following activities to assure that hazardous wastes do not find their way into New Jersey waterways:

- Reviews basin plans for sewerage system construction;
- Investigates oil spills and initiates legal action where appropriate;
- Enforces water pollution statutes and regulations;

- Monitors industrial waste treatment; and
- Monitors and surveys water quality.

Within the Division of Environmental Quality there is a Bureau of Radiation Protection which is charged with regulating radiation sources and licensees who handle radioactive materials.

In addition various citizen advisory councils play a statutory role in environmental policy formulation. The Clean Air Council, the Solid Waste Advisory Council and the Pesticide Control Council each made recommendations to the Director of the Division of Environmental Quality on pertinent issues in their respective areas of interests. The Department of Environmental Protection is not obligated to accept this advice but such advice would have to carry significant weight if only because of the politically explosive nature of most environmental issues. Similarly, the Clean Water Council and the Water Policy and Supply Council had advisory functions with respect to the Division of Water Resources.

New Jersey's Department of Environmental Protection seems to have made ample use of the technique of cross-divisional task forces and interdepartmental committees. For example, a new interdepartmental committee charged with evaluating the total environmental impact of any solid and liquid wastes put into any of the state's 350 landfill operations was established to work with the Bureau of Solid Waste Management. The committee consists of representatives from the bureaus of Potable Water, Water Pollution Control, Geology, and units involved in land-use planning and stream encroachment in the Division of Water Resources as well as navigation and riparian units from the Division of Marine Services.

As required by the State Sanitary Code, engineering design plans are submitted for each landfill. The interdepartmental committee serves as a screening unit for these plans, with each committee member evaluating the engineering report from his particular point of expertise and the effects of the landfill operation upon the environment.

The Department requires that daily logs be kept on type and source of waste being dumped in the larger landfills in the state known to be receiving large quantities of chemical wastes.

Pursuant to the statutory mandate of the Clean Oceans Act, the Department of Environmental Protection promulgated regulations banning the dumping of most toxic wastes and requiring that most other waste materials be barged to the 2000-meter depth line. Handling and loading for ocean-disposal of radioactive materials, mercury compounds, by-products from pesticide manufacture and petroleum refining are prohibited.

The regulations require that one year from the effective date the disposal of sewage sludge, chemical wastes and wastes dredged from nine major industrial waterways be dumped seaward of the 2000-meter depth line. Dumping is controlled by an annual permit system.

The techniques used by the Department of Environmental Protection to enforce various waste disposal and collection activities begin with the rules and regulations promulgated by the applicable bureaus. Pursuant to these rules with their statutory base, the department can accomplish its ends in the first instance through its permit system and standard setting as well as by vigorous prosecution of violators.

Our discussions with officials in New Jersey suggest that existing state legislation is probably adequate to accomplish the task of regulating hazardous waste disposal and treatment activities. Any problems that exist at the state level are at the level of administrative implementation.

Perhaps the single greatest obstacle to totally effective regulation is the limitation imposed on staff size and activity imposed by monetary considerations. At the same time it should be noted that the Environmental Protection Department has over 1300 full-time employees and the task of coordinating their activities is a problem in itself.

There was some dissatisfaction with the administrative performance of the Bureau of Water Pollution Control. This dissatisfaction resulted in a sweeping reorganization of the Bureau, effective September 1972, that changed the unit from a geographical division to an organization along functional lines with its own enforcement staff.

Enforcement activity in the Bureaus of Solid Waste and Water Pollution appears vigorous. In addition to their own respective enforcement staffs, each bureau tends to work with a specialized group of environmental law experts within the Attorney General's Office.

Because of common waterways and other commonalities, New Jersey has had to seek strong interstate cooperations with New York and Connecticut. Interstate compacts have been enacted but this area remains a problem.

New Jersey is blessed or cursed, depending on one's bias, with over 130 citizen advisory groups that must be consulted on various environmental issues. Although these citizen groups are advisory, they can be a substantial political force.

Pending Legislation and Recent Developments

Some 30 pieces of legislation relating to waste disposal and treatment directly or indirectly are pending in the New Jersey legislature. After discussion with the Director of Legislative Services at the State House, we concluded that only five important bills had some practical chance of passage:

- An Act providing for and authorizing funding for experimental and demonstration projects for new techniques in solid waste collection and disposal.

- An Act empowering the Department of Environmental Protection to establish pretreatment standards for sewage that may be discharged into public sewage treatment plants.

- An Act strengthening the Clean Water Council and giving it certain investigatory and subpoena powers.

- An Act authorizing the Commissioner of Environmental Protection to condition the award of sewage treatment grants on the adoption by the grantee of an equitable schedule and classification of rents, rates, fees in connection with the use of sewerage treatment facilities.

- An Act authorizing the development of comprehensive land use controls for development projects within the state.

The new Federal Water Pollution Control Act of 1972 and the Marine, Protection, Research and Sanctuaries Act seem to have largely pre-empted New Jersey's Clean Ocean Act of 1971. The full effect of these laws, however, remains to be seen.

This fall, New Jersey's Department of Environmental Protection issued a series of administrative orders to Shell Oil, DuPont, Monsanto, Mobil, Texaco and Olin, requiring each to start individual on-site wastewater treatment facilities between 1973 and 1975. These orders followed abandonment of plans by the Delaware River Basin Commission to build a multi-million dollar regional treatment plant designed to handle 71.5 million gallons of wastewater daily and serve all major petrochemical companies lining the Delaware River in Gloucester and Salem Counties. Shell was given the option of joining the Gloucester County Sewerage Authority system.

Probable Needs

Adoption of any of the proposed alternative approaches for treatment of hazardous wastes would probably require some amendment of New Jersey statutes and regulations. However, no approach suggested appears infeasible because of existing or pending New Jersey legislation.

Operational Options. The on-site processing approach to treatment pursuant to Federal law would not offer any major conflict with the existing New Jersey requirement that processed wastes not result in the discharge of hazardous materials into New Jersey waterways, but does not dictate to plants the manner by which they prevent this. No specific effluent standards must be met so long as hazardous material is not discharged into New Jersey waterways. Final treatment of wastes on-site via mobile facility would be possible as long as the necessary permit was secured and air pollution standards were met.

Off-site processing and disposal does raise the question of finding a site that would be acceptable to New Jersey authorities and does not violate New Jersey law prohibiting such processing in the wetlands or adjacent to waterways. A further complication would develop if New Jersey enacts legislation requiring a state-wide land use plan.

Pretreatment on-site and final treatment off-site raises questions both about the adequacy of pretreatment facilities and processes and the location of the off-site facilities. With respect to both activities some coordination with the New Jersey Department of Environmental Protection would be needed and conceivably amendment of New Jersey statutes to accommodate location of off-site treatment facilities.

Technical Options. Since New Jersey does not specify any particular technique or process, there would seem to be broad latitude as to technical options just as long as no hazardous effluent material is discharged.

Administrative Options. There would be no New Jersey statutes or regulations requiring specific types or effluent concentrations or process types. However, monetary incentives are available under New Jersey law and care would be taken to avail oneself of these incentives. New Jersey incentives are in the nature of tax relief and grants or subsidies. Price incentives are not present under New Jersey statute.

Any of the organizational alternatives would be possible, although public ownership and operation would be most difficult to achieve because of the political implications. Whether an existing public agency or a new authority owns and operates the facilities, there would be jurisdictional questions to be resolved and political jealousies to be aware of. These jealousies could be quite acute in the case of a new public authority which is given powers of eminent domain and cross-jurisdictional authority. Enabling legislation in New Jersey provides for the creation of such authorities, but a new statute may be in order if the activity of the authority is to be limited specifically to hazardous waste treatment and disposal.

TABLE E.4

NEW JERSEY LAWS AND REGULATIONS RELATING TO HAZARDOUS WASTES – EXISTING LAWS

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
N.J. Dept of Envir.Protection Act of 1970 Consolidate all environmental functions. Chapter 33 P.L. 1970	Advisory Promotional Rule-making Adjudicatory		Formulate comprehensive policies for the conservation of natural resources. Coordinate regional & local efforts in accordance with a unified plan including prescribing minimum qualifications for people involved. Initiate program for industrial planning. Supervise sanitary engineering facilities. Enforce state laws pertaining to the environment.

Techniques	Enforcement	Strengths	Weaknesses
Research program			
Statewide education			
Require registration & reports of programs that may result in pollution of any kind.			
Hold hearings on complaints			
Make rules and regulations			

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
N.J. Water Qual. Improvement Act of 1971 Concerning the prevention and abatement of pollution of the waters of N.J. resulting from the discharge of petroleum products, debris and hazardous substances. Inserted as part of Title 58. Chapter 173 P.L. 1971	Enforcement	Petroleum products debris - "all forms of solid waste and liquid waste of any composition whatsoever" Hazardous substances - compounds presenting serious danger to public health or welfare including damage to environment, fish, shellfish, wildlife, vegetation, shorelines, stream banks & beaches	Fast action after accident Stringent punishment as deterrent to accidents
Water & Water Supply Title 58 Art. 1,2,3,4,5,& 6 Prohibits pollution of potable water and fresh water Sets up rules and regulations re water supply and sewer systems	Rule-making	Domestic and industrial wastes, polluting substances	Supervise purity of water supplies by penalties for violations Prohibit discharge of unacceptable effluent Regulate discharge from trains and boats within designated watersheds Require permits for locating factories, workshops on watershed areas. Regulate discharge of "sludge acid"
New Jersey Clean Ocean Act of 1971 To control and prevent the threat to the quality of the State waters caused by dumping of waste into adjacent waters. Inserted as part of Title 58 Chapter 177 P.L. 1971	Rule-making	Wastes	Regulate the practice of ocean dumping. Adoption of rules and regulations concerning the loading and handling of materials within State to be disposed at sea.

Techniques	Enforcement Powers	Strengths	Weaknesses
Require prompt containment and removal of substances Prompt notification of spill	Undertake removal when responsible person fails to do so Designate injured party to remove discharge at responsible person's expense Fine Civil suits	All encompassing definitions Fast, strong enforcement powers	No real methods of preventing pollution
Assign penalties for violation Final opinion on quality of effluent Permits Approve plans for water purification plants	Fines Suits	Specifically assigns liability to factory	After the fact
Issue permits for handling materials	Withhold permits Suits Injunctions	Fast action through injunction Permit issuance attempts to control before the fact.	

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
Pesticide Control Act of 1971	Rule-making Adjudicatory	Pesticides	Adapt regulations concerning the sale, use and application of all pesticides
Chapter 177 Laws of 1971			Create the Pesticide Control Council
New Jersey Wetlands Act of 1970 Protection of natural resources in coastal wetlands Chapter 272 P.L. 1970	Adjudicatory Rule-making	Anything detrimental to wetlands	Preserve the ecological balance by regulating, dredging, filling, removing, altering or polluting

Techniques	Enforcement Powers	Strengths	Weaknesses
Make rules and regulations	Injunction Fine Embargo		
Require labelling conforming to Federal regulations			
Public hearings			
Study and investigate			
Commissioner designate wetlands	Court restraining action		Exempts State Mosquito Control Commission
Rules and Regulations	Restoration Costs		
Permits for regulated activities	Fine		

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
Solid Waste Management Act of 1970	Rules and Regulations	Solid Waste	Supervise solid waste collection and disposal facilities and operations
	Advisory		
Chapter 39 Laws of 1970	Adjudicatory		Develop state-wide regional, county and intercounty plans for solid waste management
			Create Advisory Council on Solid Waste Management
Refuse Disposal Regulations 1958			
Applicable to Hazardous Wastes		Hazardous and Chemical Wastes (Excluding Radioactive)	Shipper is responsible for proper labelling and handling of hazardous wastes to insure safe disposal Hauler responsible for operating within existing laws for transport of dangerous articles (Chapter 128, P.L. 1950) Receiver responsible for operating within existing laws No chemical wastes (liquid or solid) shall be deposited in direct or indirect contact with surface or ground waters

Techniques	Enforcement Powers	Strengths	Weaknesses
Require registration of new and existing facilities	Injunction Fine	Recognizes existence of a solid waste crisis and the need for forward management	
Promulgate rules and regulations for solid waste management			
Research and Development			
Acquire Land			
Study and Advise			
Hold Public Hearings			

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategies
Title 40 Sewerage Authorities Law 1946 Enabling Act To reduce and abate pollution of waters menacing public health	Enabling Rule-making	Sewage	Authorize counties and municipalities to form sewerage agencies Construct and maintain sewage facilities to protect waters from pollution May discharge nothing that will cause pollution of waters
Municipal Utilities Authorities Law 1957 Foster the provision and distribution of adequate supplies of water and abate pollution	Enabling Rule-making	Polluted water	Counties and/or municipalities singly or together managing waterworks and works for collection, treatment, purification, or disposal of sewage and other wastes Authorize sewerage agencies to become authorities
Title 32: 18 Interstate Sanitation Commission 1935 Cooperation of New York, New Jersey, and Connecticut for the control of future pollution and abatement of existing pollution	Rule-making Adjudicatory	Pollution	Classify waters in order to deal realistically with use of waters All sewage discharge restricted and treatment required

Techniques	Enforcement Powers	Strengths	Weaknesses
Build systems	Suits		
Inspections			
Make rules and regulations			
Charges for correction			
Providing financing for projects			
Sue and be sued			
Acquire property			
Issue bonds			
Create Authorities	Sue		
Provide for financing			
Acquire property			
Make rules and regulations			
Hearings for accused polluters			
Rules and regulations	Each state to enact own legislation for enforcement powers		
May not cause to exist any source of pollution within the district after 4/1/35 without Commission approval	Injunction		

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
Delaware River Basin Compact Pollution Control Chapter 11D Article 5	Advisory Adjudicatory	Sewage industrial and other wastes	Pollution by sewage or industrial or other waste shall not injure the waters of the basin
Control future pollution and abate existing pollution in the basin			
Transportation of Dangerous articles Chapter 128 Laws of 1950	Rules and Regulations	Dangerous articles: -flammable liquids -flammable solids -oxidizing materials -corrosive liquids -compressed gases -poisonous substances -radioactive materials (each of them are also defined)	Control conditions under which dangerous substances can be transported within the state

NOTE: Does not apply to:

- -explosives
- -flammable liquids transported in tank trucks, trailers or semi-trailers approved by Division of Motor Vehicles.

Techniques	Enforcement Powers	Strengths	Weaknesses
Investigate Build facilities to control existing or potential pollution Hold public hearings Establish standards of treatment of sewage and wastes	Insure orders to cease polluting and implement treatment	Very strong protection for one body of water	
Regulations	Fine		
Placarding	Imprisonment		

NEW JERSEY

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategies
Air Pollution Control Laws			
Air Pollution Control Act of 1954 Control and suspension of air pollution	Advisory Adjudicatory Rule-making Promotional	Air Pollutants	Create Clean Air Council Promulgate rules and regulations prohibiting air pollution Promulgate motor vehicle emission standards Require registration of those engaged in operations which may result in air pollution Clean air scholarship intern program
Air Pollution Emergency Control Act of 1967 Provides emergency powers when air pollution seriously affects the health of the public	Rule-making	Air Pollutants	Report in writing to governor who then proclaims emergency Declaration of emergency should be publicized Promulgate stand-by orders for emergency state

Techniques	Enforcement Powers	Strengths	Weaknesses
Study codes and regulations and make recommendations Study state of art Hold public hearings yearly State-wide education Inspection Financial aid for undergraduate and graduate engineering degree	Registration Injunction Fine	If emission detected and no regulation exists about that specific emission, may call hearing and direct polluter to cease	
Prohibit motor vehicles Prohibit or restrict commercial or industrial activity Prohibit incinerators Prohibit Consumption of fuel Prohibit burning & other activity contributing to pollution emergency	Motor vehicle inspection. Entry and search (except single and double family homes - need search warrant) Traffic rerouting Fine Imprisonment	Excellent emergency powers	

NEW JERSEY

Pending Legislation	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy
S200 Providing for experimentation with and demonstration of new techniques in solid waste collection and disposal.	Advisory Promotional	Solid Waste	R&D program to determine best method
S-234 Requiring pre-treatment standards for sewage	Rule-making	Sewage	Make rules and regulations establishing pretreatment standards before it can be discharged into public collection system.
S-266 To amend the Act allowing the granting of financial aid to counties and municipalities. Establish the Clean Water Council	Adjudicatory	Pollutants	To grant aid up to 30%, 25% for those projects qualifying for federal funding under FWDCA
A-702 An act regulating the phosphate content of soap, soap powders and detergents	Rule-making	Phosphates in soaps and detergents	Unlawful to manufacture use, sell, distribute, or dispose of any soap, soap powder, or detergent containing more than 5% phosphates by weight.

Techniques	Enforcement Powers	Strengths
Study and report		
Rules and regulations	Injunction	Fast, strong action
	Fine	
Require application to connect to public system	Seal off connection	Beforehand control via application
Inspection		
Grant money	Subpeona witnesses	Subpeona
To be set by Department of Environmental Protection through rules and regulations	Fine Injunction	Fast action through injunctive relief
Labelling		

PENNSYLVANIA LAWS AND REGULATIONS RELATING TO HAZARDOUS WASTES

Background

As both a large and an old industrial state, Pennsylvania has faced for some years the problem of coping with industrial wastes. Unfortunately, an important part of its natural resource base for manufacturing – Appalachia's coal fields – is also a major source of difficulty in disposing of hazardous wastes safely.

> Today, much of the (industrial) blight endures in the anthracite fields of northeastern Pennsylvania, where fires and cave-ins of the earth go on for decades after abandonment of mine sites and monstrous smoking culm dumps mar the countryside; the soft-coal fields of the west, with thousands of acres churned up by reckless strip mining; . . .*

These man-made fissures in the earth's crust cause continuing problems, as rainfall collects in abandoned mines, picks up iron oxides and mineral salts from coal dust and old explosives, and then overflows into surface streams, which supply about 80% of the water consumed in Pennsylvania. In addition, the natural processes which created the coal deposits also created porous soils and miles of underground interconnected drainage systems. When combined with Appalachia's heavy rainfall pattern of 45-50 inches per year, these conditions make geologists leary of disposal of any kind. Department of Environmental Resources (DER) officials report that only 17% of Pennsylvania is geologically suitable for receiving ordinary municipal wastes and their leachate; and this percentage includes land already used for other purposes, hence not available for disposal. The Commonwealth has therefore turned down a number of outside requests to consider providing waste disposal sites.

In 1973, Pennsylvania enacted its Clean Streams Law. However, it was not oriented toward the prevention of water pollution; it authorized official abatement action to begin only after the fact. Moreover, many small industrial plants took advantage of a loophole in the law and avoided control by the Sanitary Water Board by constructing earthen lagoons; but these lagoons, in most cases, merely postponed the day of ultimate disposal of hundreds of millions of gallons of oil, chemical, and sewage wastes. During the late 1960's, a series of major spills and pollution incidents caused severe damage to streams and focused public attention on the law's weaknesses.**

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*Pierce, Neal R., *The Megastates of America.*, N.Y.: Norton, 1972, p. 231.

**Lazarchik, Donald A., Pennsylvania's Pollution Incident Control Program," Paper presented at 25th Annual Purdue Industrial Waste Conference, May 1970.

This series of incidents contributed to the awakening to environmental dangers which has produced, in many states, stronger laws as well as more vigorous agencies to implement them. In 1971, Pennsylvania set up DER to assume the duties of 14 existing, but often competing and ill-coordinated, agencies. Governor Shafer created an extraordinary strike force, continued by Governor Schapp, of six young attorneys authorized to invoke injunctions rather than the longer and less certain procedures of criminal prosecutions and fines.* In 1972, the General Assembly completed action to amend Article 1 of Pennsylvania's Constitution by adding an "environmental bill of rights":

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people. (Section 27)

Practice of these preachings does not come without effort. Officials complain that they lack the funds needed for enforcement. However, the nation's third most populous state seems, because of its early water and air pollution abatement efforts, to have a relatively strong organization for directing and monitoring municipal control programs required by law.

Existing Laws

Table E.5 summarizes Pennsylvania's laws relating to hazardous wastes. Below, we note those provisions relevant to hazardous wastes. Table E.6 contains the text of new rules regulating hazardous solid waste. Note that the information and interpretive comments in this report are based upon examination of documents and interviews with key officials in Harrisburg. No observations were made of monitoring and enforcement actions in the field.

Pennsylvania Department of Environmental Resources (Act No. 275, 1970; Effective January 19, 1971). The law recognizes environmental functions under a new Secretary of Environmental Resources, both by abolishing some departments and commissions and transferring their functions to DER, and by retaining other agencies but placing them with DER. Units within DER important to hazardous wastes are:

- Bureau of Water Quality Management (Water Supply and Sewerage, Industrial Wastes);

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*Pierce, *Op. cit.*, p. 259.

- Bureau of Air Quality and Noise;
- Office of Radiological Health;
- Bureau of Mine and Occupational Health and Safety (Quarries and Explosives);
- Bureau of Land Protection and Reclamation (Solid Waste Management, Oil and Gas); and
- State Board of Certification of Sewage Treatment Plant and Waterworks Operators.

The law empowers DER to act in many areas, generally by issuing permits and certificates, and to assist municipal governments in planning.

The Act created, in addition to DER, three more agencies:

- Environmental Quality Board, to develop a master environmental plan for the Commonwealth and to review and regulate DER's work:

- Environmental Hearing Board, to hear appeals concerning permits and decisions issued by DER, and to issue adjudications;

- Citizens Advisory Council, to review all environmental laws of Pennsylvania, review and advise DER, and report annually to the Governor and General Assembly.

These bodies have broad review powers which, if exercised vigorously by appointees, can significantly influence environmental policy and DER's implementation of it.

Clean Streams Law (Act No. 394, 1937; as amended through 1971). The Law creates broad powers, including the regulation of "industrial wastes," which (Article I, Section 1) "shall be construed to mean any liquid, gaseous, radioactive, solid or other substance, not sewage, resulting from any manufacturing or industry . . ." Section 4 declares that Pennsylvania's policy is both to prevent further pollution and to reclaim every presently polluted stream, using permits to exercise comprehensive watershed management and control.

Among Rules and Regulations issued under the Clean Streams Law, Chapter 97, "Industrial Wastes," adopted September 2, 1971, sets forth detailed standards for a number of wastes resulting, for example, from milk processing and paperboard manufacturing. Sections 97.51-58 specify sumps, domes, and other requirements to handle wastes from oil and natural gas wells. Sections 91.71-75, "Underground Disposal," prohibit discharge into abandoned wells and specify strict conditions for disposal into mines, underground horizons, and new wells.

Chapter 101, also adopted September 2, 1971, issued "Special Water Pollution Regulations" that apply to accidents which release toxic substances into streams. Section 101.2 requires the responsible person or municipality to notify the nearest of seven DER Regional Offices, to prevent injury to downstream users, and to remove residues within 15 days.

Chapter 91, governing water resources, is notable for its emphasis upon comprehensive and basin-wide water quality management and pollution control. Section 91.31 provides that DER shall not approve a project unless it conforms to a comprehensive plan based upon information available from federal, state, and local agencies as well as the applicant.

Air Pollution Control Law (January 8, 1970, P.L 2119; amended through 1972). Pennsylvania provided an early and dramatic example of air pollution when, in October 1948, a temperature inversion over the steel-mill town of Donora, south of Pittsburgh, locked in a dense mixture of fog, exhaust, and smoke, which caused 22 deaths. The Law provides not only for control and abatement, but also for prevention of pollution, including that caused by toxic or radioactive substances, by smokes, dust, fumes, gases, odors, vapors, and similar causes. It controls burning of coal refuse and open burning of municipal refuse. It requires approval of plans to construct certain classes of air contamination sources, as well as reporting of sources. If further requires control of pollution by local governments.

In October, 1972, the General Assembly substantially amended this Law, by Act No. 245, to strengthen the powers of DER, create a permit system for stationary sources, add heavy penalties and remedies, and establish the Clean Air Fund. Section 3 (7) defined "source" to include both stationary and mobile equipment. Act No. 20, of February 14, 1972, provided for interstate agreements.

Pennsylvania Solid Waste Management Act (Act No. 241, August, 1968; amended through 1972). This Act provides for the planning and regulation of storage, college, transportation, processing, and disposal systems; requires municipalities to submit plans; requires permits for operating systems; and authorizes rules, remedies, and penalties.

Of special interest are the 1972 amendments to Rules and Regulations, Chapter 75, "Solid Waste Management," pertaining to hazardous waste, defined by Section 75.1(13) to include, but not be limited to, chemicals, explosives, pathological waste, and radioactive materials. Subchapter G, Sections 75.211 through 75.235, quoted in full in Table E.6 provides for regulation of consignment, processing, transportation, storage, and listing. The law does not specify standards, but authorizes DER to promulgate them as scientific knowledge makes them feasible.

Interstate Compacts. Various Acts authorize the Commonwealth to join with neighboring states in planning and pollution control programs of river basins (Ohio, Potomac, Susquehanna, and Delaware Rivers) as well as air sheds.

Municipality Authorities Act of 1945 (P.L. 382; amended through 1972). This broad enabling statute permits municipalities, townships, and counties to establish "bodies corporate and politic," or public agencies organized on business management principles, to provide, often on a user-fee basis, such public services as airports, tunnels, incinerators, and water works. Section 4, "Purposes and Powers," does not specify "hazardous wastes," but does include "sewage treatment works, including works for treating and disposing of industrial waste."

Industrial Development Authorities Act (August 23, 1967, P.L. 251; amended through 1972). Pennsylvania, a leading proponent of attracting industry by means of the industrial development authority device, passed this law to provide for "the incorporation as public instrumentalities of the Commonwealth and as bodies corporate and politic of industrial development authorities for municipalities, counties, and townships." This type of authority is a specific application of the general concept of the "special district" form of government, usually created in Pennsylvania under the Municipality Authorities Act. However, whereas special districts – for example, a turnpike authority or a sanitary district – both build and continue to operate facilities needed by the public, industrial development authorities generally seek merely to attract private firms into a region by helping to provide the required infrastructure, such as land and utilities. In some cases, an authority owns an industrial park and buildings, parts of which it leases to firms. A major function is often to raise capital by issuing municipal bonds which, being free of taxes, provide essential facilities to industry at costs lower than are available in commercial capital markets.

By Act No. 171 of December 29, 1971, the General Assembly amended the enabling law to define the "pollution control facilities" which development authorities may promote.

Administrative Implementation and Political Realities

Having indicated the framework of laws and regulations available to control hazardous wastes, we now turn to the practicalities of making these laws and regulations effective. Extensive examination of Pennsylvania's administrative capacities was not possible within the scope of this assignment, but the officials interviewed did make a number of observations worth reporting.

Joint Legislative Committee. Within the legislative branch, Pennsylvania seems somewhat unusual among the states in having a Joint Legislative Committee concerned with pollution control and conservation. Each of the General Assembly's chambers has its own committees. But the device of the joint committee, also used sparingly in the Congress, provides the potential for a single focus, visible to the public as well as to executive agencies and to members of the Assembly itself. This device offers a means, therefore, of coping with the problem characteristic of legislatures – fractionated interest dispersed between houses and among committees. Moreover, the charge of this joint committee includes both air and water matters, a further step toward considering different aspects of a related problem.

The Joint Committee's Executive Secretary feels that Pennsylvania's laws are adequate to allow the several alternative methods of disposing of hazardous wastes. The state's needs, in his opinion, are now two: first, to codify existing laws and regulations in environmental matters generally; second, to provide sufficient funds to administrators to carry out the policies already declared by law.

Department of Environmental Resources. This department, as its name suggests includes the administrative units most directly concerned with controlling hazardous wastes. DER officials feel that present laws are generally adequate to allow the proposed alternatives.

The mere placement within a single department of several previously independent agencies does not guarantee, of course, perfect coordination among related programs. DER, therefore, requires, as a matter of internal department routine, the coordination of reviews of applications for permits in any one field by all concerned units. DER's internal instruction, see Table E.7, cites an example:

> An air pollution permit will not be issued until all appropriate requirements for water pollution control, solid waste management, and other DER programs have been satisfied.

DER's eventual goal is to be able to issue only one permit for a given request or project.

DER appears to enjoy both strong central management, in Harrisburg, and an effective network of eight offices sited in regions of the Commonwealth, with a total staff of about 250 persons. These offices not only process permit applications and enforce laws, but also provide technical assistance to municipalities, counties, and townships in developing their required plans for water quality management and solid waste management. State officials* made clear that, although DER describes its role as assisting local governments, in reality it is directing their planning programs. It does so for a number of obvious reasons, including state legal requirements, funding by Federal agencies and DER, availability of qualified professional personnel in DER, reluctance of some local governments to carry out such programs on their own initiative, and the importance in many cases of coordinating the planning of several governments joined by a common watershed, airshed, or "wasteshed."

Environmental Quality Board. Although DER conducts the work of detailed daily administration, this Board plays the important role of reviewing DER's work. By virtue of both its legal powers and the vigorous use of them by its members, the board has a significant impact on policy. Moreover, five of its members, with full voting powers, are also members of the 18-person Citizens Advisory Council. Thus, the Board is one of the devices, if not the main device, for channeling political concerns about environmental policy and programs. Furthermore, it has administrative links with the Environmental Hearing Board. Therefore, its Administrator points out, these four bodies combine, for most practical purposes, the legislative, executive, and judicial roles in environmental matters.

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*Those interviewed are listed in Table E.8.

Comments and Trends. An important factor influencing the effective performance of these bodies is reported to be the energetic role of Pennsylvania's citizens' groups. Citizens' task forces emerge in response to issues. They attract significant amounts of time and professional expertise from lawyers, scientists, doctors, university professors, and similar kinds of persons. They prepare themselves thoroughly, present detailed technical arguments during hearings, and otherwise make their views and judgments known through the Citizens Advisory Council. They take up the time of DER officials but, as these officials admit readily, with good results.

The desire common to local governments, DER officials report, is, not surprisingly, to locate waste disposal facilities "anywhere but here." A current controversy focuses on a proposal to dispose of Philadelphia's solid wastes in abandoned mines in Northeast Pennsylvania. Although the local governments concerned oppose the idea now, its economic logic and attractions may in time overcome objections.

Some officials prefer the strategy of encouraging private enterprises rather than public agencies to develop and operate disposal services, with the Commonwealth's role limited to certification and regulation. They argue that the state could supervise private firms more effectively than it could an agency of its own creation. This strategy, of course, implies important roles for the Industrial Development Authority and Public Utilities Commission, or similar agencies devoted to waste disposal.

Probable Legislative Needs for Hazardous Waste Disposal Alternatives

Pennsylvania officials, as noted above, believe that their laws and regulations are already developed enough to enable processing and disposal of hazardous wastes by the alternative methods proposed. Minor changes or perfecting amendments, however, would likely be required to remove possible obstacles and ensure proper authorizations.

Officials indicate a number of specific though minor needs, listed below. Most relate to the solid waste management program, which has regulations governing "hazardous solid waste." Neither we nor Pennsylvania officials can suggest now the specific wording or statutory provisions required. This task of technical draftsmanship would require further detailed consultation and advice from legislative counsel to the General Assembly.

Single Permit. Present laws require different permits for different types of pollution control. Although DER tries by internal procedure to coordinate permit reviews, it feels that a single permit covering all would be preferable, both for DER and for applicants.

Monetary Incentives. To develop hazardous waste facilities will probably require incentives in the form of Federal grants or of state bond issues. The latter would require legislative authority.

Permit Industrial Development Authority to Promote Facilities. A clause may be needed in the present enabling act to specify that the Authority may include hazardous waste facilities within "pollution control facilities."

Require All Localities to Develop Solid Waste Management Plans. Present law requires planning by only those local governments having a population of more than 300 persons. This releases a number of localities from an important obligation. The law should be amended to require all localities to plan. Moreover, the law, which now allows voluntary participation, and thus implies the option of nonparticipation or withdrawal, should be amended to require compulsory participation.

Require Local Governments to Implement as Well as Plan Solid Waste Management. Present law requires only planning, which is well and good, but it should be amended to require localities to put approved plans into practice. In most cases, however, this means that state funds must also be authorized to assist construction of treatment and disposal facilities as well as to pay for other implementation expenses.

Permit DER to Approve of Solid Waste Disposal Sites. One present law reserves to County Commissioners the approval of dumping sites, for example, abandoned strip mines within the county, for solid wastes. This provision is relevant to the current proposal for disposing of Philadelphia waste in an upstate county. This provision should be rescinded. Similarly, another present law bans importation of wastes from outside the Commonwealth to be disposed of within Pennsylvania. This law should be amended to allow DER to approve such disposal according to appropriate criteria. Clearly, "anywhere but here" laws, although attractive locally, are not a long-term solution for every government.

Concept of the "Solid Waste Shed". Present law is based upon the concept of paramountcy of local political boundaries, unlike the Clean Streams Law which recognizes the need for basin-wide management. The analogous concept of wastesheds should be written explicitly into Pennsylvania's solid waste management law.

TABLE E.5

EXISTING PENNSYLVANIA LAWS RELATING TO HAZARDOUS WASTES

PENNSYLVANIA

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques	Enforcement Powers	Strengths	Weaknesses
Penn. Dept. of Environmental Resources 1/19/71 Reorganization of environmental responsibilities assigned to various state agencies Establish EQ Board Establish E.Hearing Board Establish Cit.Advis.Council Act No. 275, 1970	Rule-making Advisory Adjudicatory	Sewage Mines Solid Waste Oil & Gas Industrial Waste	Centralize environmental activities of state government Develop an environmental plan Regulate via Permits	Land acquisition Issue permits for water obstruction construction Disposition of silt deposits Issue waterworks permits Hold hearings on the purity of water supplied to the public via the Pa.Public Utility Commission Test water samples Formulate, adopt rules and regulations Subpoena power Hold hearings	Refusal to issue permits and subpeona	Centralized activity	Few specific enforcement powers No.R&D powers
Pa.Clean Streams Law 6/22/37 To preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and acquatic life, for industrial consumption and recreation. Administered by Sanitary Water Board Act No. 394, 1937 Amended 1970	Adjudicatory Rule-making Advisory	Sewage, industrial works, mine works Indus.wastes: any liquid, gaseous, radioactive, solid and other substance not sewage resulting from any mfg. or industry	Prohibit the discharge of sewage and industrial waste or any substance into the waters of Pa. which will cause pollution May accept payments to "Clean Water fund" in lieu of requiring a treatment facility after considering 5 factors [May judge pollution *[potential and regu- [late.	Issue, modify, suspend and revoke permits. Make rules and regulations. Investigate current pollution. R&D for treatment Approve plans for waste treatment.	Revoke permits Violation of purpose is declared a "nuisance" Fine Imprisonment Suits Injunction in emergency situations	Covers potential pollution	Enforcement and Manpower limited

TABLE E.5 (Continued)

PENNSYLVANIA

Law	Agency	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques	Enforcement Powers	Strengths	Weaknesses
Air Pollution Control Act 1960 P.L. 2119 Protect the air resources	Pa. Dept. of Env. Air Resources	Rule-making Adjudicatory Advisory Promotional	Air pollutants	Adapt rules and regulations for the prevention and control of air pollution Set air quality standards	Inspection Make rules and regulations Hold public hearings Set job qualifications Educational programs Research and Development	Issue orders to comply Sue Fine Imprisonment Inspections		
Air Resources Protection 1971 (Amended 1972) Act No. 245 Provide for the control and prevention of air pollution Provide guidance for design and operation of air contamination sources				Prohibit Air Pollution Provide guidance for design and operation of air contamination sources	Establish Regions for control			
Penn. Solid Waste Management Act 7-31-68 1-12-70 amended Provide for the planning & regulation of all aspects of the handling of solid wastes. Act No. 241, 1968		Rule-making Advisory Adjudicatory	Solid Wastes: "garbage, refuse & other discarded materials, including but not limited to, solid & liquid waste materials resulting from industrial, commercial & agricultural & residential activities."	Establish a cooperative state & local program of planning & technical & financial assistance for comprehensive S.W. mgmt. Require permits for operation of processing and disposal systems.	Require & approve plans for S.W. mgmt. systems Financial aid Permit Make rules & regulation R&D	Disapprove plans "Action in mandamus" Withhold or revoke permit Fine Imprisonment	Public utility permits may not withhold or revoked if the public will be adversely affected. Before the fact regulation via approval of plans & granting permit.	

TABLE E.5 (Continued)

PENNSYLVANIA

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques	Enforcement Powers	Strengths	Weaknesses
Solid Waste Management 1969		Hazardous Waste	Not permitted in a sanitary landfill				
			Excluded from transfer stations - must be transported directly to disposal site				
Regulations pertaining to hazardous wastes			Special storage procedures to be approved by the Department				
			Shall not be collected with other wastes				
			May be incinerated in facilities designed in accordance with Department standards				
			Very specific regulation about handling, identifying and listing hazardous wastes				

TABLE E.5 (Continued)

PENNSYLVANIA

Law	Nature of Powers	Types of Hazardous Substances	Basic Control Strategy	Techniques	Enforcement Powers	Strengths	Weaknesses
Municipality Authorities Act of 1945 Provide for the creation of authorities as corporate and political bodies Amended 1972 P.L. 382			To allow the formation of a corporate body to more effectively deal with the following projects: public buildings (school, judicial) transportation marketing shopping terminals bridges tunnels flood control projects highways, parkways traffic distribution centers parking spaces airports parks recreative grounds sewer & sewer systems sewage treatment works (including industrial waste) collection, removal or disposal of refuse by incineration, landfill, etc. steam heating plants incinerators water works & water supply works swimming pools, playground lakes low head dam hospitals motor buses, subways industrial development projects Specific duties for County Water Authorities		All those necessary to carry out strategy		

Table E.6

Excerpts from Pennsylvania Rules and Regulations, Department of Environmental Resources*

CHAPTER 75. SOLID WASTE MANAGEMENT

Subchapter A. GENERAL PROVISIONS

MISCELLANEOUS

75.1 Definitions

The following words and terms, when used in this Chapter, shall have the following meanings, unless the context clearly indicates otherwise:

(13) Hazardous waste -- [Solid waste with certain inherent dangers.] Any waste which by virtue of its quantity or content presents a hazard to the individuals handling it, a hazard to public health, or potential pollution to the air or waters of the Commonwealth or makes land unfit or undesirable for normal use. This category shall include but is not limited to chemicals, explosives, pathological waste and radioactive materials.

Subchapter F. STANDARDS FOR SOLID WASTE INCINERATOR FACILITIES

75.193. Hazardous waste.

Hazardous wastes may be incinerated provided that special provisions are made in the design and operation of the facility and only with Departmental approval.

Subchapter G. HAZARDOUS SOLID WASTE

GENERAL

75.211. General requirement.

Whenever hazardous waste is produced and alternate reclamation or reuse is not possible, the collection, transportation, processing and disposal shall be accomplished in accordance with the provisions of this Subchapter.

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* Issued under authority of Act. No. 241 of July 31, 1968, and adopted ________ 1972.

Table E.6 continued

75.212 Consignment of waste.

(a) No consignment of solid waste shall be made to another without the disclosure of its hazardous nature.

(b) No consignment of solid waste should be made to another without the assurance that subsequent handling and disposal shall be accomplished in a satisfactory manner and in accordance with the laws and regulations of this Commonwealth.

PROCESSING AND DISPOSAL OF WASTE

75.221. Authorized sites and methods.

No receiver of hazardous solid waste shall use any other than sites or methods permitted pursuant to the act for hazardous waste processing or disposal.

75.222. Transportation of waste.

The transportation of hazardous solid wastes shall not be done in a manner which will present a rsik to the transporter or the general public or which may result in pollution of the environment.

75.223. Processing of waste.

The processing of hazardous solid waste to render it non-hazardous shall not be done in a manner or way which, in itself, creates additional hazards or environmental pollution.

75.224. Handling methods for waste.

No disposal site shall accept hazardous solid waste for disposal without having established a handling method which precludes or minimizes the occurrence of hazardous incidents.

75.225. Storage for processing or disposal.

No storage of hazardous solid waste materials prepartory to further processing of disposal shall be in such locations or quantities or under such conditions as may be deemed unsafe by the Department.

Table E.6 continued

LISTING OF WASTE

75.231. Department to maintain list.

(a) The Department shall maintain a multiple list of hazardous or potentially hazardous materials as determined by experience, investigation and literature.

(b) The lists shall be so divided as to provide an element of delineation.

(c) Any material or substance proven to be hazardous by actual contamination or injury shall be placed on the list with the proper information to guide subsequent handling.

75.232. Effect of listing or non-listing.

(a) The naming or omission of any material or substance should not be construed to be the ultimate determination of classification.

(b) No substance should be considered wholly free of suspicion as a hazardous agent solely based on its absence from the Department's listing.

75.233. Listing by toxicity.

(a) Each item or class of item shall be listed by common name, chemical name,trade name or otherwise identified.

(b) The lower limits of toxicity shall be indicated in the listing.

(c) Recommended handling and disposal methods when known shall be added to the listing to assist in upgrading management practices. Known unsatisfactory handling practices shall be specifically delineated.

75.234. Listing by flammability and explosiveness.

(a) Each item or class of item shall be listed by common name, chemical name, trade name or otherwise identified.

(b) The conditions or limits of flammability or explosiveness shall be indicated in the listing. The listing shall include a lower limit of the quantity considered hazardous even though respectfully handled.

Table E.6 continued

(c) The recommended handling and disposal methods shall be added to the listing when known. Unsatisfactory handling practices shall be specifically delineated.

75.235. Listing by pathogenicity.

(a) Each item or class of item shall be listed by common name, chemical name, trade name or otherwise identified.

(b) Quantity limitations which contribute to the hazardous quality of the waste shall be provided.

(c) Both desirable and undesirable disposal methods shall be included in the listing.

75.236. Listing by radioactivity.

(a) Wastes shall be described by specific common name and chemical name.

(b) The hazardous materials listing shall not be considered all inclusive and shall be updated and expanded as new information becomes available.

(c) References concerning the hazardous nature of materials placed on the listing shall be maintained.

(d) Federal and State standards for handling and disposal shall be followed.

Table E.7

Copy of Department of Environmental Resources Internal Instructions Concerning Issuance of Department of Environmental Resources Permits

Regional Air Pollution Control Engineers
Regional Sanitary Engineers
Regional Sanitarians

Wesley E. Gilbertson - Deputy Secretary
for Environmental Protection

As many of you know, we are now developing procedures to better coordinate the issuance of permits in the Department in accordance with policy established sometime ago. It is intended that these procedures will provide for the following:

1. Notification (in a clear and concise manner) to any applicant of all permit requirements with respect to all rules and regulations of DER.
2. Coordinated review of permit applications by DER staff.
3. The issuance of all required DER permits, for a specific facility, at one time. That is, for example, an air pollution permit will not be issued until all appropriate requirements for water pollution control, solid waste management, and other DER programs have been satisfied.

While the procedures to accomplish the above are being developed, you are asked to make every effort to achieve these objectives during your routine permit processing operations. Each of you is hereby made responsible for ascertaining whether another Bureau is to be involved. Coordinated permit processing procedures have been covered previously in directives from the environmental protection bureaus. Some of these directives called for merely notifying the appropriate bureau when a permit was received that may fall under their regulations. More positive action is now required.

It is planned to involve the Regional Environmental Protection Coordinators in the development of these procedures. It also appears that some permit applications may have to be modified in order to prevent redundancy and simplify both the applicant's task and the DER review.

You will soon be receiving additional guidance and requests for comments on proposed procedures.

Table E.8

Key Officials Interviewed in Harrisburg, Pennsylvania

See Figure E.2

Department of Environmental Resources

Wesley E. Gilbertson
Deputy for Environmental Protection and Regulation

William Buccarelli
Chief, Division of Solid Waste Management
Bureau of Land Protection and Reclamation

Ernest Giovannitti
Chief, Division of Industrial Wastes
Bureau of Water Quality Management

Environmental Quality Board

Mary C. Harris
Administrative Officer

Joint Legislative Air and Water Pollution Control and Conservation Committee

Peter S. Duncan, III
Executive Secretary

APPENDIX F

DEVELOPMENT OF ECONOMIC DECISION MAPS

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INTRODUCTION

The cost of disposing of a hazardous waste includes the cost of transporting it to a processing site and the actual cost of processing it at that site. The former cost is proportional to the distance the waste must be transported, and the latter depends on the utilized capacity of the processing facility. Processing costs per unit of waste are smaller in large facilities, reflecting the economies of scale of large operations.

In most cases, optimization of the disposal strategy requires a balancing of these two factors, since the larger processing facility is often farther from the source than the smaller facility. (If it is not, there is no selection problem; we choose the larger and nearby facility.) The selection problem can be framed in terms of the two alternative strategies diagrammed in Figure F.1.

We adopt as conventions that: (a) Processing Site 1 has a smaller capacity than Site 2 (i.e., $T_1 < T_2$), and (b) Processing Site 1 is closer to the source than Site 2 (i.e., $M_1 < M_2$). Of course, the waste output of the source is less than or equal to the capacity at either processing site ($T_0 \leqslant T_1$, $T_0 \leqslant T_2$). In more practical terms, Strategy 1 might be on-site disposal at the source (in this case $M_1 = 0$ and $T_0 = T_1$), and Strategy 2 might be collection of all comparable wastes from the region for treatment at a local regional site. Alternatively, Strategy 1 might be treatment at the local regional site and Strategy 2 collection of waste from several sources for treatment in a National Treatment System.

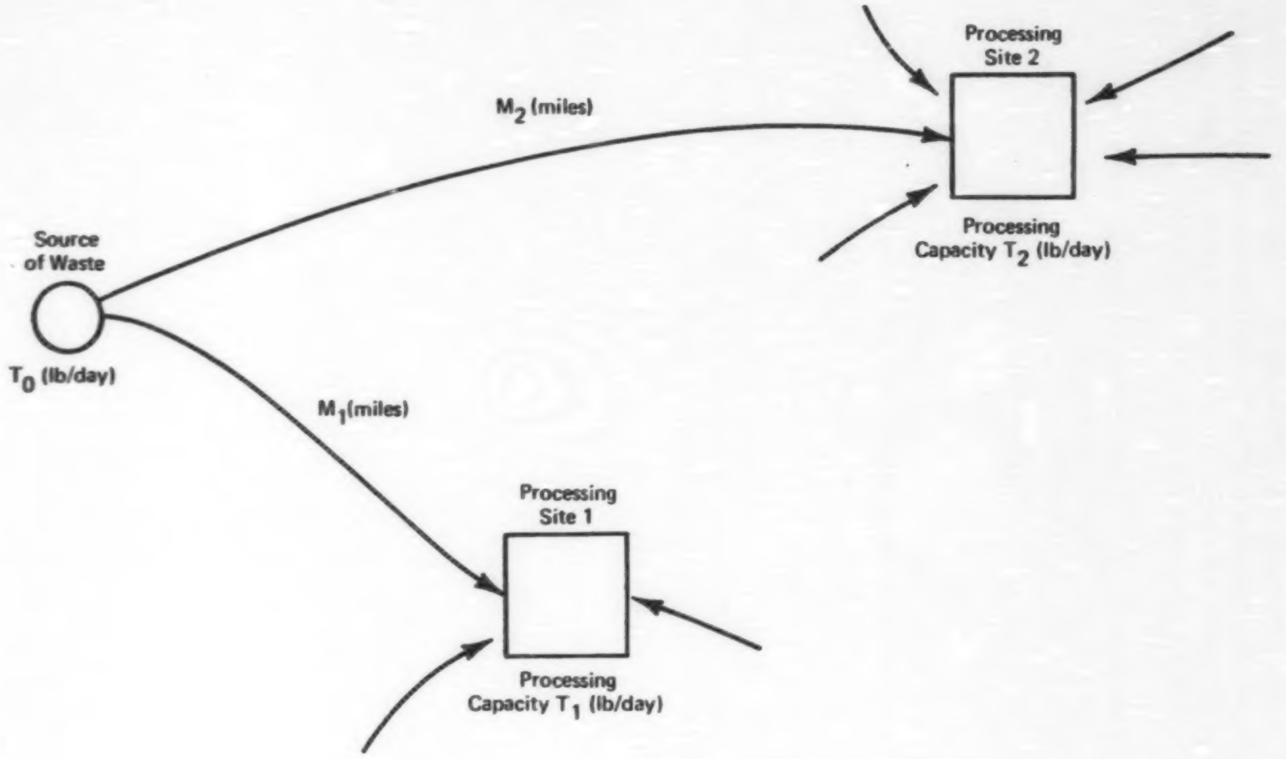

Processing
Site 2
M_2 (miles)
Source
of Waste
Processing
Capacity T_2 (lb/day)
T_0 (lb/day)
M_1(miles)
Processing
Site 1
Processing
Capacity T_1 (lb/day)

FIGURE F.1 ALTERNATIVE PROCESSING STRATEGIES

DETERMINING THE LOWER COST STRATEGY

The lower cost strategy is determined as follows from the relative costs of processing and transport. We define the unit costs (cost per pound of hazardous chemical contained in the waste) as:

c_p = processing cost.
c_{HW} = handling cost (loading and unloading).
c_{HR} = handling cost of residue.
c_{TW} = transport cost of waste per mile.
c_{TR} = transport cost of residue per mile.
c_F = final disposal cost.

The total unit cost, c_i, for processing by strategy i is then

$$c_i = c_{HWi} + c_{TWi}\left(M_{Wi}\right) + c_{pi} + c_{HRi} + c_{TRi}\left(M_{Ri}\right) + c_{Fi} \qquad (1)$$

where:

M_{Wi} = miles waste is transported
M_{Ri} = miles residue is transported.

For most strategies, some of these terms will be zero. For example:

- if there is no residue for final disposal, $c_{HRi} = c_{TRi} = c_{Fi} = 0$
- If the processing and final disposal occur at the same site, $c_{HR} = c_{TR} = 0$
- If the waste is processed at the source, $c_{HWi} = c_{TWi} = 0$

The difference in cost between two strategies (i = 1 and i = 2) is

$$\Delta c = \Delta c_{HW} + c_{TW}\left(\Delta M_W\right) + \Delta c_p + \Delta c_{HR} + c_{TR}\left(\Delta M_R\right) + \Delta c_F \qquad (2)$$

where:

$$\Delta c \equiv c_1 - c_2$$

Again, for most pairs of strategies, some of the terms in Equation (2) will be zero. For example

- If both strategies involve moving the waste from the source, $\Delta c_{HW} = 0$

- if the final residue is disposed of at the processing site,

$$\Delta c_{HR} = c_{TR} = 0$$

Of the cost terms appearing in Equation (2), we assume that only the processing cost, c_p, depends on capacity (throughput). The chemical processing literature shows that the capacity dependence is well represented by

$$c_p \propto T^{-0.4} \qquad (3)$$

Therefore:

$$\begin{aligned}\Delta c_p &= c_{p1} - c_{p2} \\ &= c_{p1} \left(1 - \frac{c_{p2}}{c_{p1}}\right) \\ &= c_{p1} \left[1 - \left(\frac{T_1}{T_2}\right)^{0.4}\right] \qquad (4)\end{aligned}$$

The breakeven condition can be expressed by setting $\Delta c = 0$ in Equation (2) and solving for ΔM_W (or ΔM_R, if that is important in comparing the two alternatives). Doing this yields:

$$-\Delta M_W = \frac{1}{c_{TW}} \left[\Delta c_{HW} + \Delta c_p + \Delta c_{HR} + c_{TR} (\Delta M_R) + \Delta c_F \right] \qquad (5)$$

Substituting Equation (4) and rearranging terms gives:

$$-\Delta M_W = \frac{c_{p1}}{c_{TW}} \left[1 - \left(\frac{T_1}{T_2}\right)^{0.4}\right] + \frac{1}{c_{TW}} \left[\Delta c_{HW} + \Delta c_{HR} + c_{TR} (\Delta M_R) + \Delta c_F \right] \qquad (6)$$

Further rearrangement, including division by c_{p0}, the unit processing cost at a capacity equal to the source load, gives:

$$(-\Delta M_W)\ \frac{c_{TW}}{c_{p0}} = \frac{c_{p1}}{c_{p0}} \left[1-\left(\frac{T_1}{T_2}\right)^{0.4}\right] + \frac{1}{c_{p0}} \left[\Delta c_{HW} + \Delta c_{HR} + c_{TR}(\Delta M_R + \Delta c_F\right]$$

$$(-\Delta M)\ \frac{c_{TW}}{c_{p)}} = \left(\frac{T_0}{T_1}\right)^{0.4} \left[1-\left(\frac{T_1}{T_2}\right)^{0.4}\right] + \frac{1}{c_{p0}} \left[\Delta c_{HW} + \Delta c_{HR} + \Delta c_{TR}(\Delta M_R) + \Delta c_F\right] \quad (7)$$

The subscript 0 refers to the source of waste, and in general $T_0 \leq T_1 < T_2$. When the source level (T_0) is determined for a given type of processing for a given waste, the last term in Equation (7) is just a number, A. Thus Equation (7) can be written as:

$$(-\Delta M)\ (\frac{c_{TW}}{c_{p0}}) = \left(\frac{T_0}{T_1}\right)^{0.4} \left[1-\left(\frac{T_1}{T_2}\right)^{0.4}\right] + A \quad (8)$$

Since ΔM has dimensions of miles and the ratio c_{TW}/c_{p0} has dimensions of $(\text{miles})^{-1}$, the expression $(-\Delta M)\ (c_{TW}/c_{p0})$ is dimensionless. For convenience we designate this dimensionless expression as ΔB.

Equation (8) can be used to determine some general rules for bringing wastes from separate sources together. Suppose, for example, that A in Equation (8) is zero, either because the steps associated with the term are not included in either processing alternative or because they are the same in each alternative. Consider a network of waste sources, each producing a load T_0 of waste, and spacing on a rectangular grid of spacing g.*

Finally, consider the following alternatives:

Process on-site, or
Collect waste from 4 or 9 sources.

We assume each source has the same quantity of waste as the on-site process; each is located on a square grid; and the waste from each source is brought to a processing site at the center of the square (Figure F.2). Determine over what range of grid sizes (values of g) each alternative is best. First, let us compare collection by 4's with on-site processing. In this situation,

---

*Actual spacing in miles is $g(c_{p0}/cT_w)$.

$$
\begin{aligned}
T_1 &= T_0 \\
T_2 &= 4T_0 \\
T_0/T_1 &= 1 \\
T_1/T_2 &= 0.25 \\
A_1 &= A_2
\end{aligned}
$$

where:

T_0 = lb/day process on-site
T_1 = lb capacity of on-site facility
T_2 = capacity of off-site facility
A_1, A_2 = handling and final disposal costs

From Equation (8):

$$\Delta B = (1)\ (1 - 0.25^{0.4}) = 0.425$$

From the geometry of the network, Figure F.3:

$$B_2 = \frac{\sqrt{2}g}{2}, \quad B_1 = 0$$

Therefore, collection by 4's is better than on-site processing if

$$B_2 - B_1 < 0.425$$

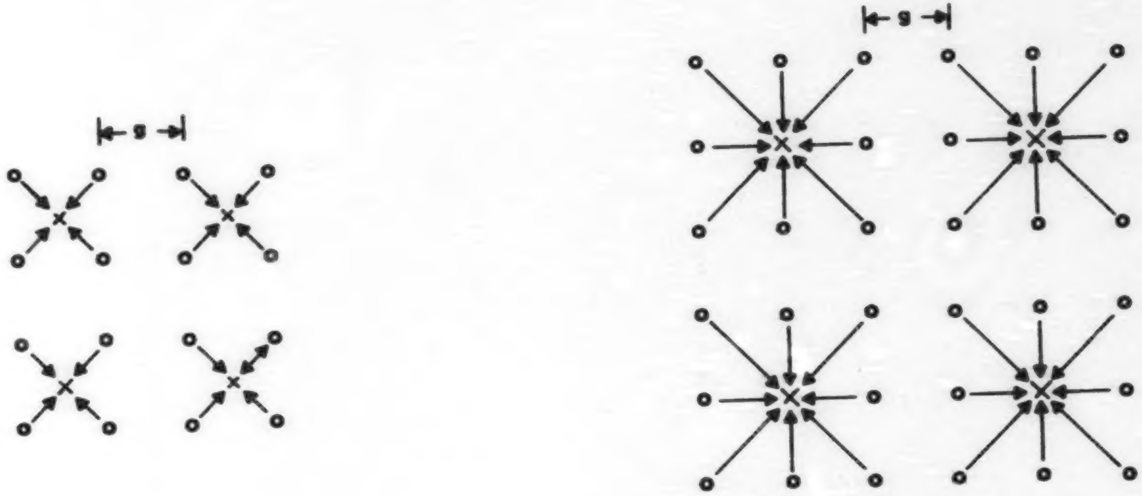
or if

$$\frac{\sqrt{2}g}{2} < 0.425$$

Solving for g gives

$$g < 0.601.$$

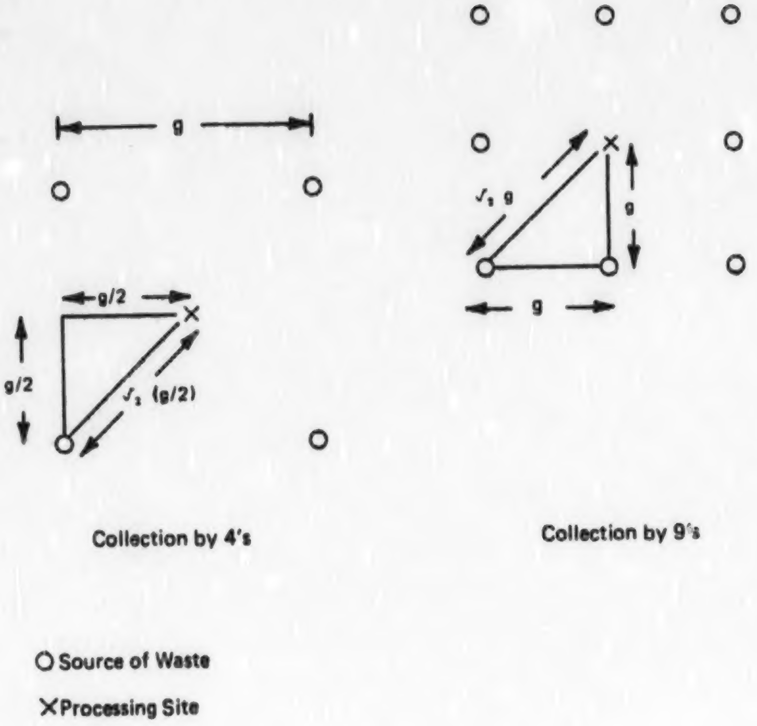
Therefore, collection by 4's is better than on-site processing if the grid size, g, is less than 0.601.



Collection by 4's

Collection by 9's

FIGURE F.2 COLLECTION ALTERNATIVES


g
g/2
g/2
√2 (g/2)
√2 g
g
g
○ Source of Waste
× Processing Site

Collection by 4's

Collection by 9's

FIGURE F.3 TRANSPORT GEOMETRY

Now let us compare collection by 9's with collection by 4's. For this

$$T_1 = 4T_0$$
$$T_2 = 9T_0$$
$$T_0/T_1 = 1/4$$
$$T_1/T_2 = 4/9$$
$$A_1 = A_2$$

From Equation (8),

$$\Delta B = 0.1595$$

From geometry

$$B_2 = \sqrt{2}g; \quad B_1 = \frac{\sqrt{2}g}{2}$$

Therefore

$$\sqrt{2}g - \frac{\sqrt{2}g}{2} < 0.1595$$

or

$$g < 0.226.$$

The results of these calculations for higher degrees of collection are summarized in Table F.1.

TABLE F.1

EFFECT OF DIMENSIONLESS GRID SIZE ON DEGREE OF COLLECTION

Optimum Degree of Collection	Range of Grid Sizes
No collections	larger than 0.601
By 4's	0.226 to 0.601
By 9's	0.121 to 0.226
By 16's	0.0767 to 0.121
By 25's	0.0532 to 0.0767
By 36's	0.0407 to 0.0532
By 49's	0.0302 to 0.0407
By 64's	0.0240 to 0.0302
By 81's	0.0197 to 0.0240

The dimensionless grid size g can be converted to miles (m) according to

$$m = g\left(\frac{c_{p0}}{c_{TW}}\right)$$

The ratio c_{p0}/c_{TW} probably lies in the range of 10 to 1000 for most processing methods. The data shown in Table F.1 are plotted in Figure F.4 for values of c_{p0}/c_{TW} of 1 to 1000. The parallel bands rising to the right show the ranges of grid size for which each degree of collection is optimal. "Collection by 1" is on-site processing.

Figure F.4 is used as follows. If the source grid size (distance between sources) is 30 miles, and the value of c_{p0}/c_{TW} is 100, locate the point on the decision map that corresponds to these values. The point lies in the "Collect by 4's" band, so collection by 4's is less expensive than on-site processing or collection from a larger number of sources.

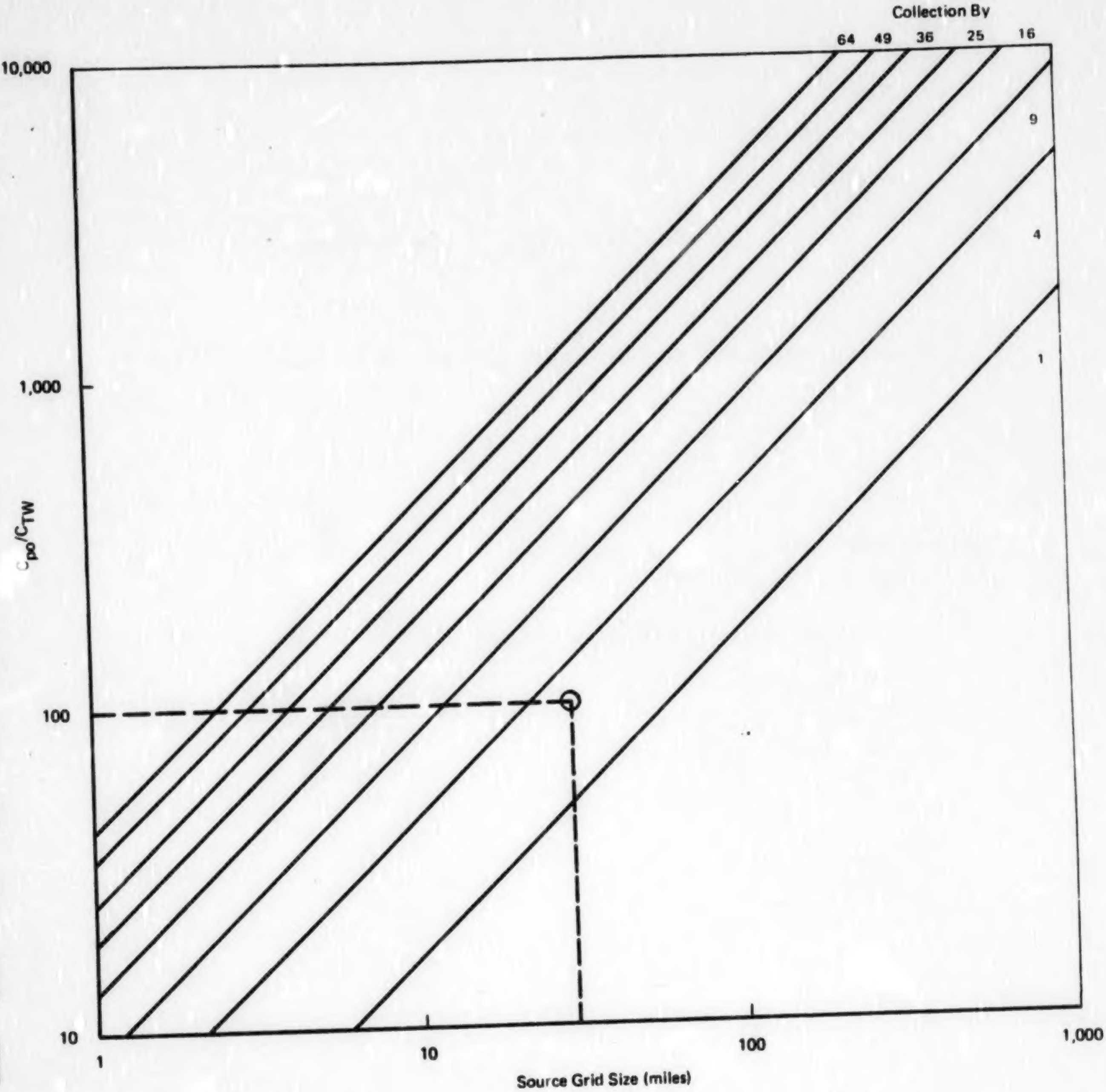


FIGURE F.4 EFFECT OF GRID SIZE ON DEGREE OF COLLECTION

The area to be served by a facility collecting waste from N_c sources logated "g" miles apart is

$$A = N_c g^2 \qquad (13)$$

Substituting Equation (12) into Equation (13) yields:

$$A = (1.23) \quad \frac{g^{0.91}}{(c_T/c_{po})^{1.09}} \; (g\, c_T/c_{p0})^{1.09} \qquad (14)$$

Substituting Equation (9) into Equation (14) and solving for "g" gives:

$$g = \left(\frac{A}{1.23}\right)^{1.10} \quad \left(\frac{c_T}{c_{p*}}\right)^{1.20} \left(\frac{T_0}{T_*}\right)^{0.48} \qquad (15)$$

the contour line to be expressed in terms of source size (T_0), the standard base cost and capacity (c_{p*} and T_*) and the area A.

These contours are shown on the decision map, Figure F.5.

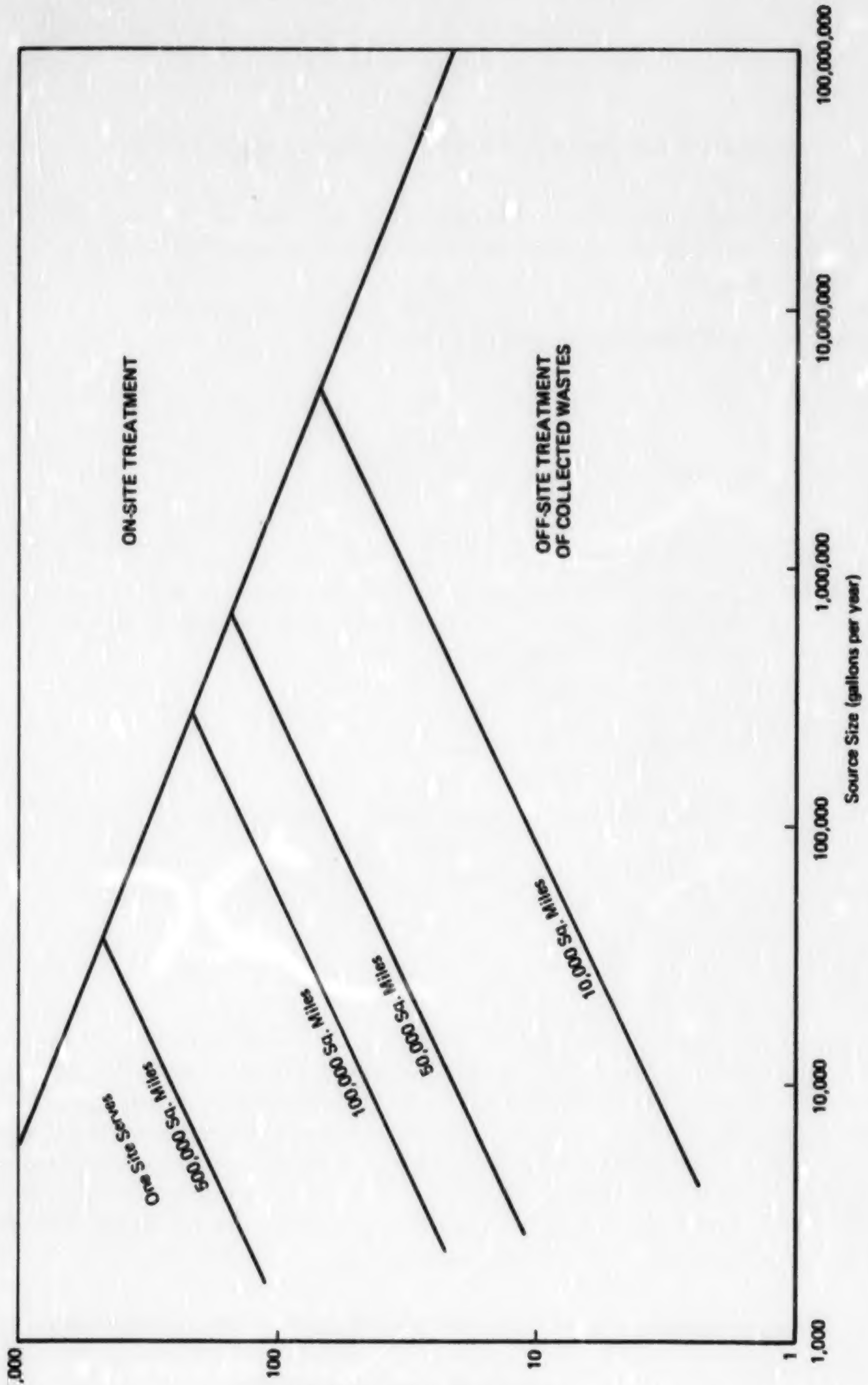


FIGURE F.5 TYPICAL DECISION MAP BASED ON SOURCE SIZE

DETERMINING THE BEST STRATEGY FROM SOURCE SIZE

Although we had developed a means for selecting a strategy on the basis of cost ratio, we found that the decision maps can be expressed in a more useful form by converting the cost ratio to source size.

Processing costs of different capacities are related by

$$c_{po}/c_{TW} = (c_{p*}/c_{TW}) \left(\frac{T_*}{T_o}\right)^{0.4} \qquad (9)$$

c_{p0} is the unit processing cost at one waste level and source capacity T_0 gallons per year, and c_{p*} and T_* are similarly related and refer to a standard base waste load used to estimate cost. The breakeven line between on-site processing is given by

$$c_{p0}/c_{TW} = 1.66g \qquad (10)$$

Substituting Equation (10) into Equation (9) and solving for g yields:

$$g = \frac{1}{1.66} \left[c_{p*}/c_{TW}\right] \left(\frac{T_*}{T_o}\right)^{0.4} \qquad (11)$$

For a given waste, we estimate the unit processing cost c_{p*} at a standard base capacity T_*. Equation (11) can then be plotted for that process on a decision map with coordinates "g" (mean source separation) and T_0 (source size). An example is shown in Figure F.5. In the region above and to the right of the breakeven line, on-site processing is optimal. Below and to the left of the line, off-site processing is optimal. Below and to the left of the line, off-site processing is more economical. Contours showing the optimal area to be served by each offsite processing facility can be drawn on the map to indicate the best configuration of regional processing facilities for off-site processing.

The optimal number of sources to be collected (N_c) for off-site processing is given by

$$N_c = \frac{1.23}{(g\ c_T/c_{po})}\ 1.09\ (gc_T/c_{po})^{1.09} \qquad (12)$$

IMPACT OF "NONHAZARDOUS" WASTES ON ECONOMICS OF TREATING HAZARDOUS WASTES

The design of a system to dispose of a certain type of hazardous waste can be seriously deficient unless the context in which the design is made is suitably comprehensive. For example, we can design a system (series of processing facilities) to process chlorinated hydrocarbons, based on the nature and volume of these wastes. However, other hydrocarbon wastes, which are not hazardous by our ground rules, are processed in the same way – incineration with scrubbing of the exhaust gases. A commercial processor who accepts these wastes can also treat the hazardous chlorinated hydrocarbons, and has an immediate and significant scale advantage over a processor who accepts only hazardous hydrocarbons.

A system designed to process only hazardous hydrocarbons may never be used since the sources of these wastes may find commercial processors closer at hand and less expensive. To illustrate this possibility, consider the following situations:

(1) Sources of hazardous hydrocarbons exist on a square grid of size g_h miles. The source level of each source is T_0 gallons per year (gpy).

(2) Additional sources (at level T_0 gpy) of nonhazardous hydrocarbons exist on a square grid such that the grid size for all sources (hazardous plus nonhazardous) is g_t miles. g_t is related to g_h by

$$g_t = \sqrt{\alpha}\, g_h \tag{16}$$

where α is the fraction of the sources that produce hazardous wastes.

(3) One system of processing sites (H) is available to process only the hazardous wastes, and another system (T) to process all wastes.

How much of the hazardous waste would go to H and how much could be more cheaply disposed of using the T system? Hazardous waste sources for which $d_t - d_h > \Delta$ will use the T system rather than the H system, where d_t is the distance from the source to the closest T center and d_h is the distance to the closest H center. Δ is the allowable extra transport distance to a T center made possible by the greater economies of scale enjoyed by the T center:

$$\Lambda = N_h^{-0.4} - N_t^{-0.4}$$

where N_h and N_t are the design values of numbers of sources to be collected for common processing in the H and T systems, respectively.

In order to express Δ analytically in terms of g_h and g_t (or g_h and α), we must describe the decision map in an equation. This cannot be done exactly, since the map is discontinuous with a range of g values associated with each N. (Recall that in terms of dimensionless distances, the two-dimensional decision map shrinks to a one-dimensional line.) However, the map can be approximated by plotting g versus N and fitting a line through the midpoint of the g values. This is done in Figure F.6. The resulting empirically determined line is

$$N = 1.23g^{-1.09} \qquad (17)$$

Substituting Equation (17) into equation (16) yields

$$\Delta = 0.92\ (g_h^{0.436} - g_t^{0.436}) \qquad (18)$$

and since $g_t = \sqrt{\alpha}\, gh$, Equation (18) becomes

$$\Delta = 0.92\ (1 - \alpha^{0.218})\ g_h^{0.436} \qquad (19)$$

The question then is, "For how many of the hazardous waste sources is $d_t - d_h \leq \Delta$? First, we assume that all hazardous waste sources are a minimal distance from an H center, namely $d_h - g_h/\sqrt{2}$. Most are farther away, so this assumption biases the analyses in favor of the H centers. With this assumption, the decision criterion can be changed to

$$d_t \leq R \qquad (20)$$

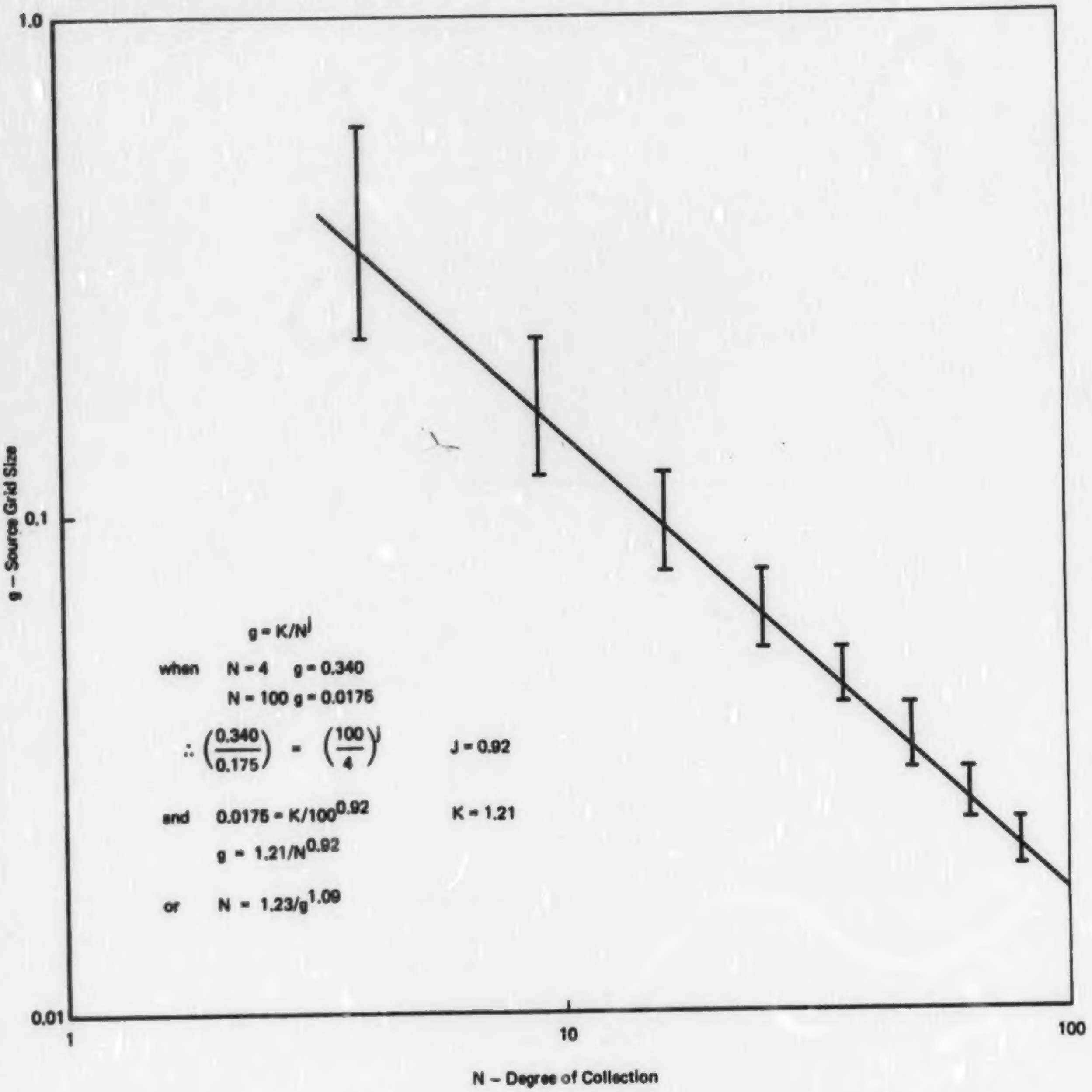
where

$$R = \Delta + g_h/\sqrt{2} \qquad (21)$$

or

$$R = 0.92\ (1 - \alpha^{0.218})\ g_h^{0.436} + 0.707\ g_h \qquad (22)$$

Those hazardous waste sources which lie within a circle of radius R centered at a T center will use the T center. Assuming that hazardous sources are uniformly distributed, the fraction failing to meet the above criterion and using the H center is equal to the fraction of the total area outside of circles of radius R centered at the T centers. This in turn depends on the relative values of R and the separation (S) between T centers. Figure F.7 shows the situation. The desired fraction (f_h) is the ratio of the shaded area to the rectangular area (S x S). From geometry, the following relations apply



$g = K/N^J$

when $N = 4 \quad g = 0.340$

$N = 100 \quad g = 0.0175$

$\therefore \left(\frac{0.340}{0.175}\right) = \left(\frac{100}{4}\right)^J \qquad J = 0.92$

and $0.0175 = K/100^{0.92} \qquad K = 1.21$

$g = 1.21/N^{0.92}$

or $N = 1.23/g^{1.09}$

FIGURE F.8 EMPIRICAL FITTING OF DIMENSIONLESS DECISION MAP

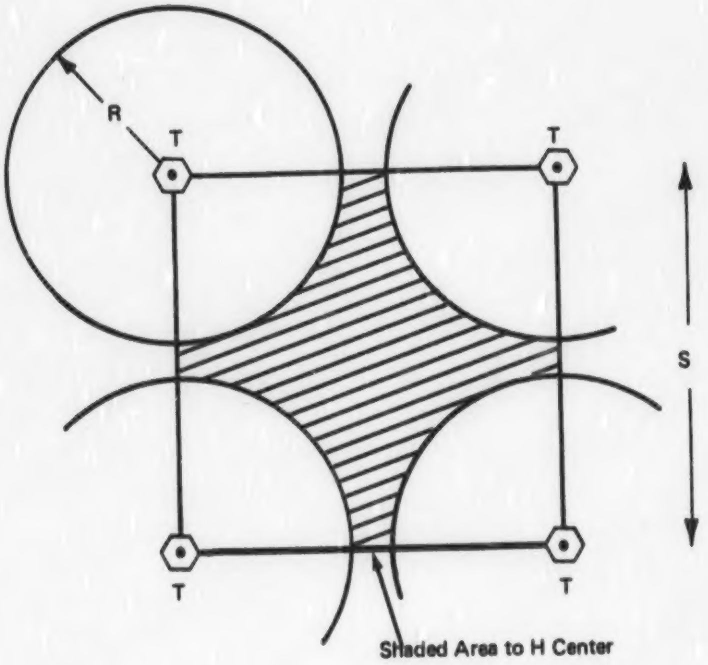

R
T
T
T
T
S
Shaded Area to H Center

FIGURE F.7 COLLECTION SITE DISTRIBUTION GEOMETRY

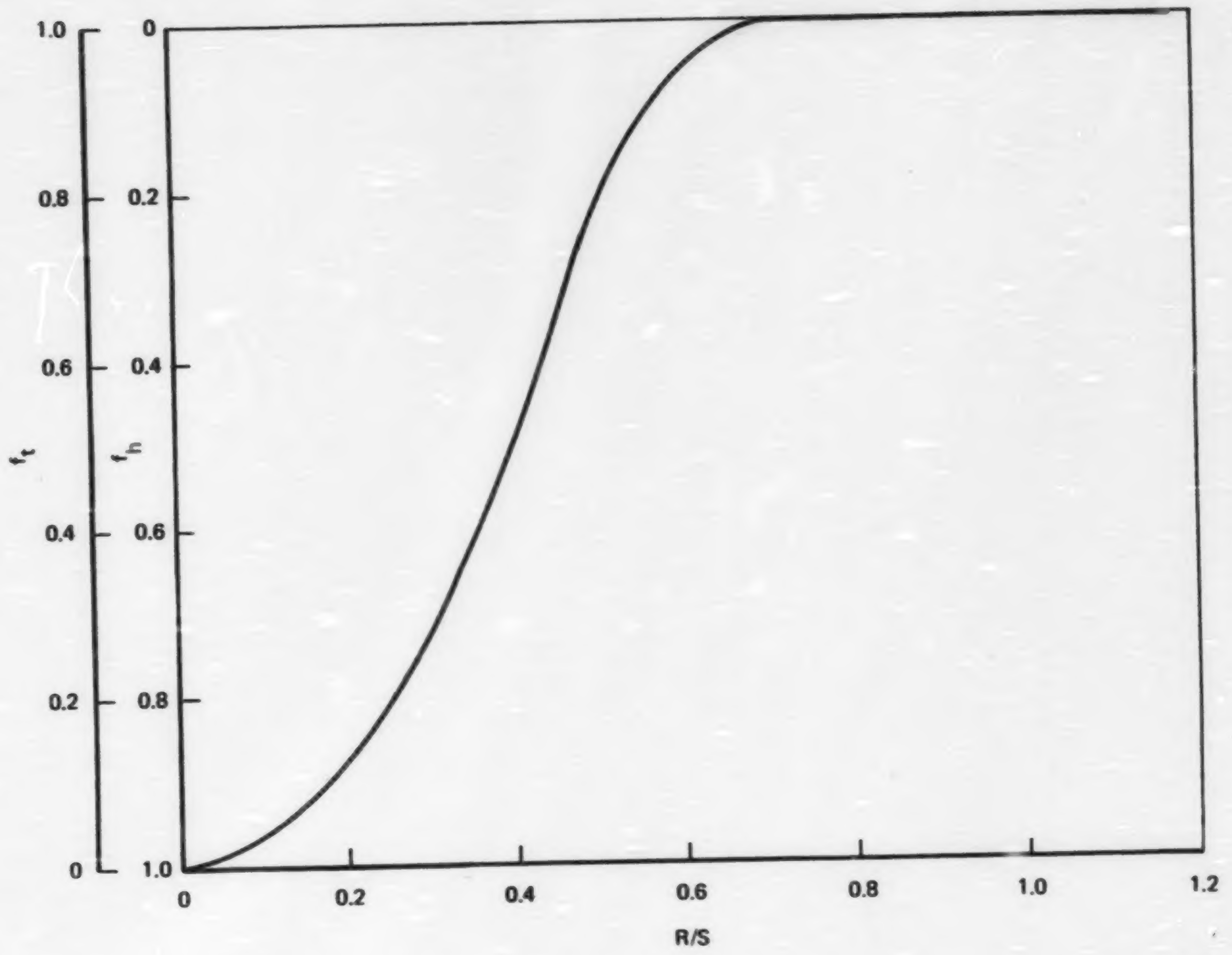


FIGURE F.8 DISTRIBUTION OF SOURCES BETWEEN T AND H CENTERS

$$f_h = 1 - \pi\left(\frac{R}{S}\right)^2 \qquad R < \frac{S}{2} \tag{23a}$$

$$f_h = 1 - [\pi\left(\frac{R}{S}\right)^2 (1 - \frac{\alpha}{90}) + 2\left(\frac{R}{S}\right)\sin\frac{\alpha}{2}] \qquad \frac{S}{2} < R < \frac{S}{\sqrt{2}} \tag{23b}$$

where: $\cos\frac{\alpha}{2} = \frac{S}{2R}$ $\qquad R > \frac{S}{\sqrt{2}}$ (23c)

$f_h = 0$

The middle relation is necessary to account for overlapping of the circles. Values of f_h and f_t $(1 - f_h)$ are plotted against R/S in Figure F.8. f_h is interpreted as that fraction of the hazardous waste sources which will utilize H centers rather than T centers.

All that remains is to express R/S in terms of the g_h and α, the given parameters. Equation (22) expresses R in these terms. The separation between T centers is given by

$$S = \sqrt{N_t}\, g_t \tag{24}$$

Using Equation (17),

$$\begin{aligned} S &= \sqrt{(1.23\ g_t)^{-1.09}}\ g_t \\ &= 1.11\ g_t^{-0.545}\ g_t = 1.11\ g_t^{0.455} \end{aligned} \tag{25}$$

Since $g_t = \sqrt{\alpha}\ g_{h1}$ Equation (25) becomes

$$S = 1.11\ \alpha^{0.227}\ g_h^{0.455} \tag{26}$$

Combining Equations (22) and (26) yields

$$\frac{R}{S} = 0.828\left(\frac{1-\alpha^{0.218}}{\alpha^{0.227}}\right) g_h^{-0.019} + \frac{0.636\ g_h^{0.545}}{\alpha^{0.227}} \tag{27}$$

We are interested in the range of R/S from zero to 0.707 (f_h from one to zero). To map out the performance of the competitive systems, we:

a) substitute values of α and g_h into Equation (27) and compute R/S;

b) determine f_h from Figure F.8;

c) list that value of f_h at the proper coordinate on an α versus g_h plot; and

d) draw contours of constant f_h on the map.

The $\alpha - g_h$ decision map is shown on Figure F.9. The map is used as follows: Given g_h and α, enter the map and locate the corresponding point. Read off the value of f_h. For example, if $g_h = 0.1$ and $\alpha = 0.3$, the corresponding map point falls between the 0.10 and 0.30 f_h contours. By interpolation, $f_h = 0.25$. This value is interpreted to mean that for the assumed conditions 25 percent of the hazardous waste sources would use the H system rather than the T system.

The map is conservative; that is, the percentage of hazardous sources shown to use the H centers is biased on the high side. This bias arises from the simplifying assumption that all hazardous sources are a minimal distance from an H center; see Equations (20) – (22) and the preceding discussion. In fact, 50 percent is the maximum H center usage. If all sources were hazardous ($\alpha = 1.0$, the best situation for H centers), the H and T systems would be the same and each would be expected to receive 50 percent of the waste on the basis of symmetry.

Examination of the map shows that only at small grid sizes and large α does the H system get much of the business anticipated in its design. The T system has a decided advantage because of: (a) inherent economies of scale, and (b) the fact that optimal collection practice puts T centers closer together than H centers.

This decision map can be used iteratively in H system design to show that for most values of α and g_h, the optimum H system is no system at all. Assume, for example, that $g_h = 0.1$ and $\alpha = 0.5$. From the decision map $f_h = 0.60$. Therefore, only 60 percent of the hazardous wastes goes to the H center and the rest look like nonhazardous wastes to the system designer. Therefore, of 100 sources, 70 go to T centers [50 + 0.4 (50)] and 30 go to H centers [50–0.4(50)]. We can compute a new α and g_h based on this allocation of sources and get

$$\alpha = (0.5)\ (0.60) = 0.3$$

$$g_h = (0.1)\sqrt{\frac{50}{.30}} = 0.129$$

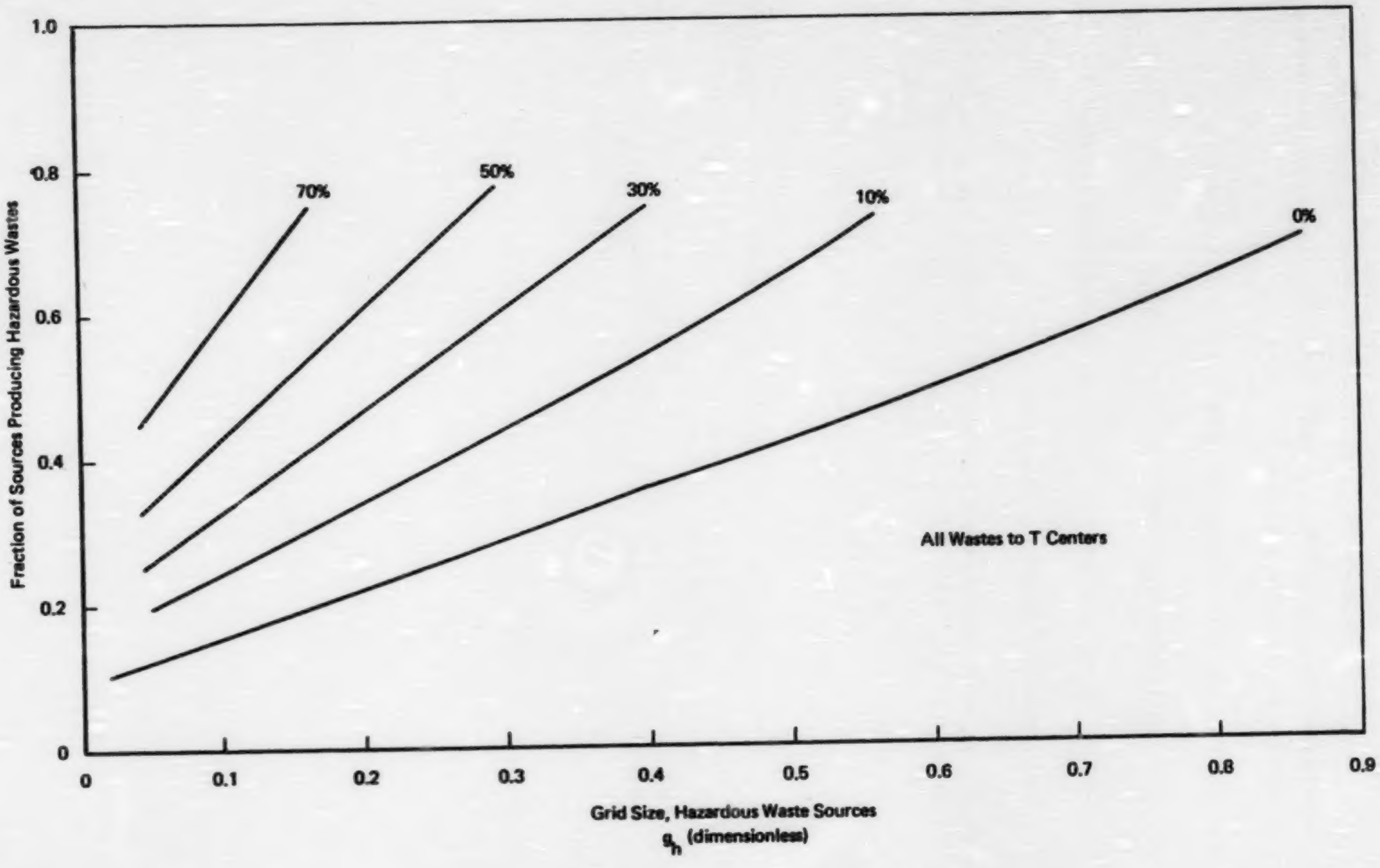


FIGURE F.9 FRACTION OF HAZARDOUS SOURCES USING H CENTERS

At these coordinates, $f_h = 0.15$ so only 15 percent of the remaining sources assumed to use the H centers would in fact do so (4 or 5 of 100 total).

Recomputing α and g_h again gives

$$\alpha = (0.3)\ (0.15) = 0.045$$

$$g_h = 0.129 \sqrt{\frac{30}{.045}} = 0.334$$

From the decision map at these coordinates, $f_h = 0$, and all sources go to the T centers.

This iterative progression suggests what may be otherwise obvious. The H centers, which have an inherent disadvantage due to economies of scale, cannot recover their costs and stay in business if an appreciable fraction of the total wastes to be treated is nonhazardous. The H centers could of course remain in business by pricing their services below cost.

EFFECT OF SOURCE SIZE DIFFERENCES ON RESULTS OF USING THE DECISION MAPS

The decision model analysis is based on the assumption that all sources are of the same size. In fact, sources vary markedly in size within a geographical area. The principal error that can occur in applying the model with its uniform source size assumption is that a larger-than-average source located near the boundary of the area served by the collection site may find on-site processing cheaper than using the site recommended by the model. The likelihood of this occurring can be calculated as a function of source size and distance from the collection site.

Consider a collection site of capacity T_1 serving N sources. The mean source size T_0 is

$$T_0 = T_1/N \qquad (28)$$

A large source of size T_j ($T_j > T_0$) is located on the boundary of the area served by the site and is a distance

$$M_m = \frac{(\sqrt{N}-1)}{\sqrt{2}} \, s \qquad (29)$$

from the site. (M_m is the maximum distance from a source in a square grid pattern to a site located at the center of the N sources served.)

The unit cost of using the site for disposal is

$$c_s = c_{p1} + M \, c_{tw} \qquad (30)$$

and the cost of treating on-site is

$$c_j = c_{pj} \qquad (31)$$

Use of the central site is cheaper if

$$c_s < c_j \qquad (32)$$

or if

$$c_{p1} + Mc_{tw} < c_{pj} \qquad (33)$$

Solving for M gives

$$M < \frac{c_{pj} - c_{p1}}{c_{tw}} \tag{34}$$

The "six tenths" rule, which gives $c_p \alpha T^{-0.4}$ allows Equation (34) to be expressed as

$$M \frac{c_{tw}}{c_{p1}} < \left(\frac{T_1}{T_j}\right)^{0.4} - 1 \tag{35}$$

Solving for T_j/T_1, the ratio of large source size to collection site capacity, gives

$$(T_j/T_1) < \left[\frac{1}{M \frac{c_{tw}}{c_{p1}} + 1}\right]^{2.5} \tag{36}$$

Equation (36) shows that if (T_j/T_1) is less than the right-hand term, the source will use the collection site. If (T_j/T_1) is larger, on-site processing is more economical. As the distance M increases, the limit of (T_j/T_1) decreases, showing that the farther the source is from the site, the smaller the source which allows economical on-site processing.

The farthest a source can be from a collection site is M_m, Equation (29). M_m is a function of N and g, the source grid size. Also g was empirically related to N by

$$g \cdot \left(\frac{c_{tw}}{c_{po}}\right) = \frac{1.21}{N^{0.917}} \tag{37}$$

Substituting Equations (28) and (29) into Equation (36) and setting the term c_{p0}/c_{p1} which arises equal to $N^{0.4}$ yields

$$(T_j/T_1) < \left[\frac{1}{\left(\frac{0.840\ (\sqrt{N}-1)}{N^{0.517}}\right) + 1}\right]^{2.5} \tag{38}$$

The source size T_j can be expressed in terms of mean source size, T_0, since $T_1 = NT_0$. The equation can be generalized to source-site distrances (M) less than M_m by inserting $\alpha = M/M_m$ into the right-hand term. Thus, Equation (38) becomes

$$(T_j/T_0) < \left[\frac{1}{\alpha\left(\frac{0.840\ (\sqrt{N}-1)}{N^{0.517}}\right) + 1}\right]^{2.5} \qquad (39)$$

For a collection site serving N sources, all sources smaller than T_j computed from Equation (39) with $\alpha = 1$ will use the collection site. For $\alpha < 1$, say $\alpha = 0.5$, all sources of size T_j computed from Equation (39) and lying with αM_m of the site will use the site. Those lying farther away (from αM_m to M_m) will enjoy cheaper disposal on-site. Assuming a uniform distribution, the fraction of sources (and the fraction of any given size source as well) lying within αM_m of the collection site is

$$p = \left(\frac{\alpha M_m}{M_m}\right)^2 = \alpha^2 \qquad (40)$$

p is therefore the probability that a source of size T_j will use the collection site.

Using Equations (39) and (40) yields the answer to the original question. These equations were solved for serveral values of N and α. The results are shown on Figure F.10. Source size, expressed in multiples of the mean source size T_0, is plotted on one axis. The probability that a source of size T_j will utilize the collection site is plotted on the other axis. The figure shows that the larger the collection site, the less sensitive the use of the site is to the occurrence of sources larger than the mean. For example, for a site serving 9 sources, all sources smaller than 3.1 T_0 will use the site no matter where they are located in the site collection area. Only about half the sources as large as 4 T_0 would use the site. As N increases to 16, the comparable sizes are 5 T_0 and 6.6 T_0, and at N = 25, they are 7.3 T_0 and 9.9 Ts,0. We conclude, therefore, that the utility of the model is not seriously jeopardized by the assumption of uniform source size, particularly where the model recommends collection of upwards of 10 sources.

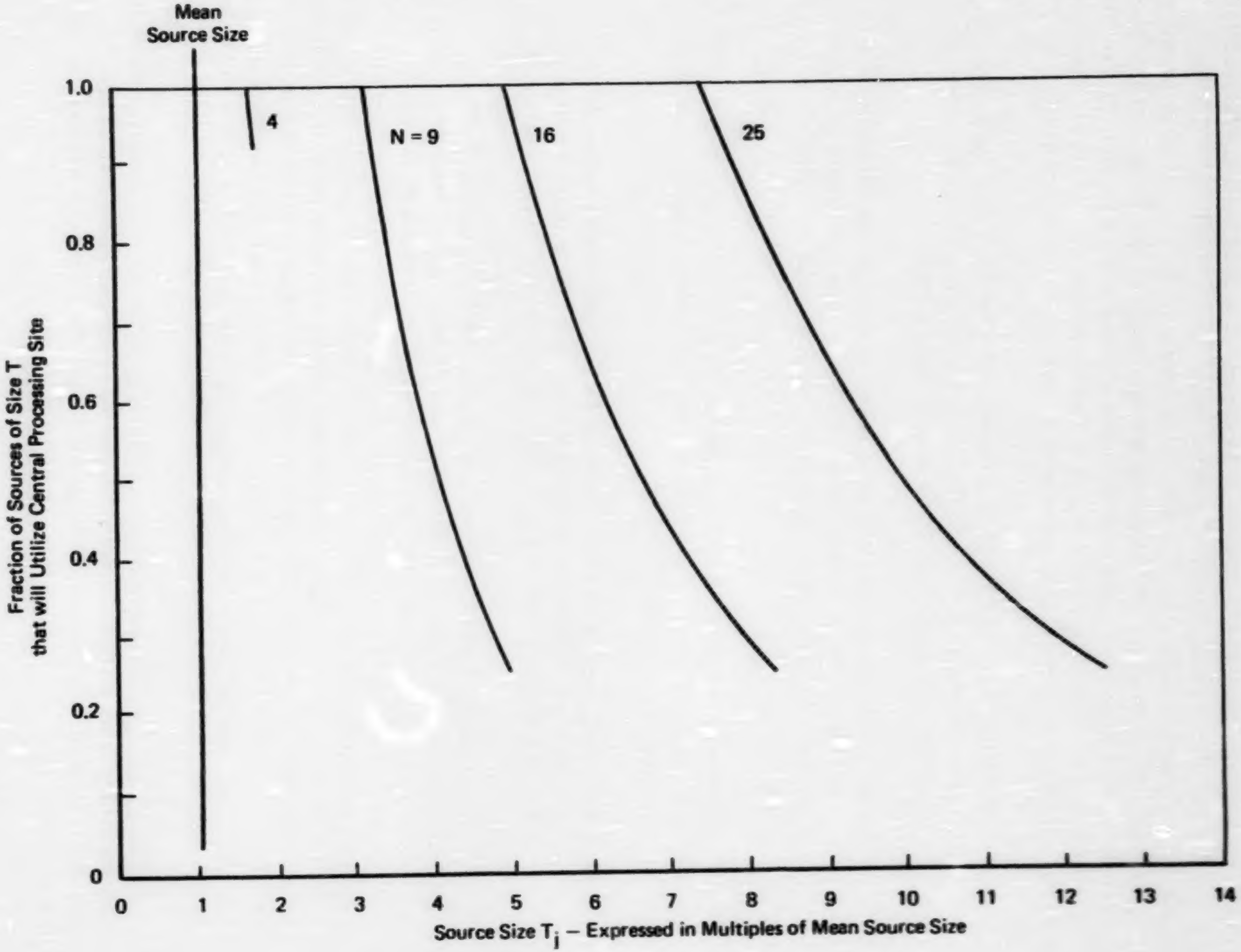


FIGURE F.10 EFFECT OF SOURCE SIZE ON MODEL UTILITY

UTILIZATION OF THE DECISION MAPS ON SELECTED WASTES

To determine the true effectiveness of the model, we selected a few wastes and carried them through the modeling process. We chose incineration with alkaline scrubbing as the process and selected from our 35 categories of wastes those that could be treated by incineration and scrubbing: the organic pesticides, many of the miscellaneous organic compounds, and the aromatic and aliphatic organochlorine compounds. Next we identified waste streams in the Northeast region which fit these categories. Given the lcoation of these sources and the description of type and amount of waste generated by each, we:

- Estimated the cost for on-site processing of waste from the largest source. When this cost is divided by the transportation cost, the smallest value of c_{p0}/c_{TW} applicable to any of the samples sources results.
- Established the on-site processing costs for each of the smaller sources according to the six-tenths scale rule. These costs are higher than that estimated for the largest source and therefore result in higher values of c_{p0}/c_{TW}.
- Estimated the average source grid size (g) by taking the square root of: the area in which the sampled sources were found divided by the number of sources.
- Plotted c_{p0}/c_{TW} versus g for each of the sampled sources on the decision map and listed the degree of collection shown on the map for each source. The largest source (smallest c_{p0}/c_{TW}) has the smallest degree of collection.

On the basis of waste source data from the field, we identified 15 sources of chlorinated hydrocarbons as to composition and volume. Six represented continuous sources; the remaining nine were "one-shot." The data are summarized in Table F.2.

The six continuous sources range in volume from 750,000 gallons/year to 5000 gallons/year. One-shot sources range down to 800 gallons. To define the number of regular sources that this sample represents, we took the six continuous sources and four of the one-shot sources. The inclusion of the latter four was arbitrary and based on the hypothesis that there will continue to be one-shot sources, although perhaps not as many as in the recent past.

The choice was also governed by our strategy of biasing our analyses, within the uncertainties present, toward a recommendation for on-site processing. As is discussed later, this bias is supported by few sources (large source grid size), low processing costs and high transportation costs.

TABLE F.2

FIELD DATA FOR ORGANO WASTES

Waste				
Type	Percent	Volume*	Frequency **	Projected Distance from Treatment Facility (miles)
DDT	30	20,000 gpy	c	70–80
PCB	80–95	40,000 gpy	c	300
PCB	25–30	5,000 gpy	c	30
PCB	30–45	10,000 gpy	c	320
PCB	—	15,000 gpy	c	290
Nitrochlorobenzene	13	750,000 gpy	c	25
DDT	5	20,000 gal	0	110
DDT	10	40,000 gal	0	50
DDT	10	30,000 gal	0	25
DDT	10	14,000 gal	0	80
DDT	—	30,000 gal	0	30–70
Hexachlor	60–65	1,000 gal	0	380
Malathion	14	700–800 gal	0	280
PCB	—	25,000 gal	0	385
PCB	75	3,000 gal	0	108

* gpy = gallons per year.

** Continuous (c); One-Shot (0).

The processing costs were estimated for the largest waste sources (750,000 gpy) and scaled by the six-tenths rule for the smaller sources.

Table F.3 summarizes the operating cost for such an incinerator/scrubbing system operating at design capacity of 750,000 gallons/year. Note that caustic soda used to neutralize and scrub out the HCl generated, would be the single largest cost item, 13 tons/day or $1100/day, based on $80/pound sodium hydroxide. If a cheaper source of alkali could be found, for example, lime, savings in the neutralization requirements, could be substantial, although labor costs will go up somewhat for the handling of this solid material. However, whichever alkali is used for the neutralization, we assume it will be used both for the on-site recovery and for any off-site treatment systems that we are comparing in the model. Therefore, these items would cancel out. The 19.4¢/gallon for depreciation of the facility is based on our estimated $700,000 investment cost, depreciation over five years. Figure F.11 shows a breakdown of our investment cost. The utility requirements of chemicals, cooling water, and fuel are detailed in Table F.4 and Table F.5.

In summary, the processing costs for the 750,000 gallons/year source were estimated to be:

Chemical and Utilities	54¢/gallon
Labor	2
Capital Related Costs	26
	82¢/gallon

Only the scale-dependent costs (labor and capital related costs) are relevant to decision map analyses of the source data. The sum of these costs is c_{p0} = 28¢/gallon.

Transportation costs were obtained from several places. The literature* cites line-haul costs of liquids at 5¢/ton-mile in the 750- to 1500-gallon range and 3¢/ton-mile in the 3800- to 5000-gallon range. (Line-haul costs are associated directly with road miles traveled and do not include terminal handling or administrative costs.) From private communications with a company transportating wastes, we obtained estimates of costs at $1.50/mile for 5000-gallon tankers, which figures to about 7.5¢/ton-mile. Since high transportation costs bias the analyses toward on-site processing, we chose to use the 7.5¢/ton-mile (or 0.03¢/gal-mile) figure.

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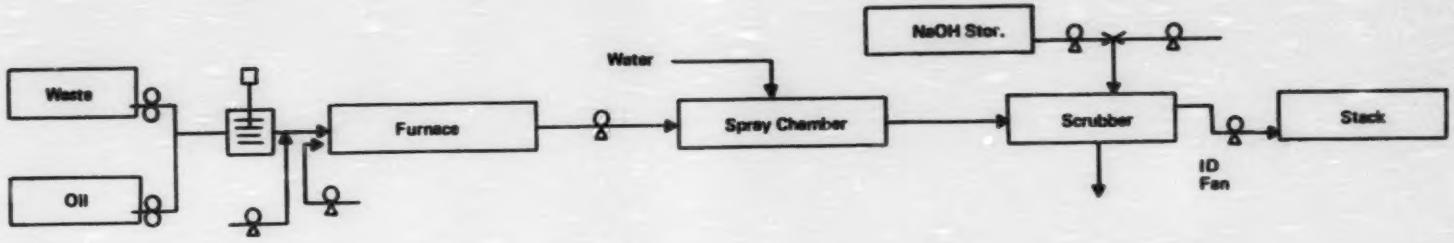
* Oi, W. Y., and A. P. Hurter, Jr., Economics of Private Truck Transportation, Wm. C. Brown Co., Dubuque, Iowa (1965), pp 170-171.

TABLE F.3

INCINERATION OF CHLORINATED HYDROCARBONS – MODULAR COST*

Cost Item	Units/Hr	Units/Day	Units/Hr	Unit Cost	$/Day	¢/Gal	
Caustic Soda	1,140 lb	27,400 lb		$0.04	1,100	36.6	
Cooling Water	70 M gal	1,680 M gal		0.05	84	2.8	
Fuel	180 gal	4,320 gal		0.10	432	14.4	53.8
Labor (incl. fringe)		8 hrs/day		5.50	44	1.46	
Overhead		50% labor		—	22	.73	
Depreciation (20% FCI/yr)			$140,000/yr		583	19.43	
Maintenance (5% FCI/yr)			35,000/yr		146	4.8	
Insurance & Taxes (2% FCI/yr)			14,000/yr		58	1.93	28.3
				Total	$2,469/day		82.1¢/gallon

*Basis: 3,000 gal/day (equivalent to 750,000 gal/yr) chlorinated hydrocarbon. Operation 24 hrs/day, 5 days per week (240 days/yr). Fixed capital investment $700,000.



	Purchased Equipment	
Fuel Storage 20,000 gal (carbon steel)	$ 6,000	CE March 1964
Waste Storage	28,000	
Fuel Metering Pump	300	
Waste Metering Pump (Alloy)	700	
In-Line Mixer	400	
Air Compressor 400 cfm at 100 psi	10,000	
Air Blower (included in furnace)	– –	
Furnace 30 MM Btu/hr	40,000	CE March 1969
Spray Chamber	20,000	
Scrubber (13-ft diam x 40 ft high)	100,000	CE March 1964
Scrubber Fan	10,000	
Sodium Hydroxide Storage 40,000 gal	10,000	
Pump plus Flowmeter	600	
Stack 100 ft x 36 in. (stainless)	8,000	CE March 1964
Total Purchased Equipment	$234,000	
	x 3	
Total Fixed Capital Investment	$702,000	

FIGURE F.11 INCINERATION COST OF CHLORINATED HYDROCARBONS – CAPITAL COSTS

TABLE F.4

CALCULATION OF AUXILIARY FUEL REQUIREMENTS

Incineration of Chlorinated Hydrocarbons - Modular Disposal Cost

Example: Polychlorinated Biphenyls or Chlorobenzenes

Heat of combustion (use hexachlorobenzene at 509 K Cal per gm/mole):
Mol Wt C_6Cl_6 = 72 + 6 (35.5) = 72 + 213 = 285

$$\frac{509\text{K Cal}}{285\text{ g}} \times 1{,}800 = 3{,}200 \text{ Btu/lb from combustion}$$

$$C_6Cl_6 + 6O_2 \longrightarrow 6CO_2 + 3Cl_2$$

Heat Input for 80 F ⟶ 1832 F

285 lb hexachlorobenzene

Flue Gas	C_p Btu/16 F		Δt	Lb Gas/mole C_6Cl_6
Cl_2 3 moles	0.17	0.26	1752 F	213
CO_2 6 moles	0.28			264
N_2 28 moles	0.27			1060
O_2 3 moles	0.26			96
40 moles				1633

$$\frac{1633\text{ lb flue gas}}{285\text{ lb } C_6Cl_6} \times 5.75 \text{ lb flue gas/lb } C_6Cl_6$$

5.75 lb x 0.26 x 1,752 F = 2,570 Btu/lb to heat flue gas

Between 8,000 and 10,000 Btu/lb are required to sustain stable combustion of liquid wastes, although the above heat balance indicates that C_6Cl_6 at 3,200 Btu/lb could reach a combustion temperature of 1832F with no heat losses.

To create a fuel mixture of 10,000 Btu heat content would require mixing C_6Cl_6 with fuel oil

$$(x)\ (3{,}200) + (1 - x)\ (19{,}000) = 10{,}000$$

$$x = 0.57 \text{ lb } C_6Cl_6 \text{ per } 0.43 \text{ lb fuel oil}$$

Therefore, use one pound fuel oil per pound chlorinated hydrocarbon.

TABLE F.5

CHEMICAL UTILITY REQUIREMENTS

A. Caustic Requirements (NaOH solution)

HCl 1040 lb/hr (from 1350 lb/hr C_6Cl_6)

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$$

$$NaOH + HCl \longrightarrow NaCl + H_2O$$ Use 4¢/lb

$$\frac{40}{36.5} \times 1040 \text{ lb/hr} = 1140 \text{ lb/hr}$$

40 lb NaOH
35 lb Cl

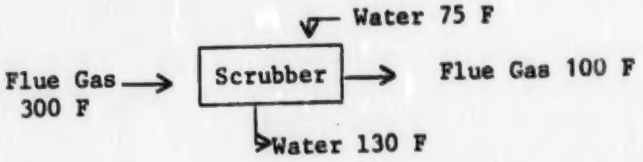
B. Water Requirements for HCl Scrubber

$$Q = 37{,}460 \ \frac{\text{lb}}{\text{hr}} \text{ flue gas } \left(0.27 \ \frac{\text{Btu}}{\text{lb °F}}\right) \overset{\Delta\text{°F}}{(2960 - 300)} = W \left(\overset{\substack{\text{vap}\\ 300\text{ F}}}{1193} - \overset{\substack{\text{liq}\\ 80\text{ F}}}{48} \ \frac{\text{Btu}}{\text{lb}}\right)$$

W = 23,500 lb/hr = 2,820 gph = 47 gpm

$$23{,}500 \times \frac{359 \text{ ft}^3}{18 \text{ lb}} \times \frac{760\text{°R}}{492\text{°R}} = 724{,}000 \text{ ft}^3\text{/hr water vapor}$$

$$\text{Water } C_p = 0.47 \ \frac{\text{Btu}}{\text{lb°F}} \qquad \text{Gas } C_p = 0.27 \ \frac{\text{Btu}}{\text{lb°F}}$$



$$\text{Dry flue gas } 37{,}460 \ \frac{\text{lb}}{\text{hr}} \times 0.27 \times (300\text{–}100)\text{°F} = 2{,}023{,}000$$

$$\text{Water } \left(23{,}500 \ \frac{\text{lb}}{\text{hr}} + 2{,}100 \ \frac{\text{lb}}{\text{hr}}\right) \left(1193 - 98 \ \frac{\text{Btu}}{\text{lb}}\right) = 28{,}032{,}000$$

$$\text{HCl solution in NaOH} = \begin{array}{l}\underline{916{,}000}\\ 30{,}971{,}000 \ \frac{\text{Btu}}{\text{hr}}\end{array} = W\,(130\text{–}75) \qquad W = 563{,}000 \text{ lb/hr}$$

(67,520 gal/hr)

The value of c_{p0}/c_{TW} for the largest source is therefore $28/0.03 = 933$, which is rounded to 1000 within the accuracy of the calculation. Values for the other continuous sources (and one added 1000 gallon/year source to cover the range of the field data) are shown below.

Source Volume (gpy)	(c_{p0}/c_{TW})*
750,000	1,000
40,000	3,200
20,000	4,300
15,000	4,800
10,000	5,600
5,000	7,400
1,000	10,000

The locations of these sources range from Massachusetts to West Virginia, an area roughly 500 miles by 300 miles. Since we assume that the data represent 10 effective continuous sources, the effective source grid size (separation between sources) is

$$g = \sqrt{\frac{300 \times 500}{10}} \cong 120 \text{ miles}$$

The area could be defined to be smaller, say 300 miles by 300 miles. However, in keeping with our strategy to bias the analyses toward on-site processing, we chose the higher value.

The seven source points are plotted on Figure F.12. The collection bands in which each of the source points fall are shown below:

Source Volume (gpy)	Degree of Collection
750,000	9 - 16
40,000	49
20,000	64
15,000	64
10,000	81
5,000	100+
1,000	100+

---

*Values for smaller sources computed from

$$(c_{p0}/c_{TW}) = (1000)\left(\frac{750{,}000}{\text{Volume}}\right)^{0.4}$$

The interpretation is that even if all 10 sources found in the area generated 750,000 gallons of waste per year they should be collected for processing at a single site. If all sources were of 40,000-gpy volume, as many as 49 (39 more than in the total original sample) should be collected. If all sources were even smaller, still higher degrees of collection are called for. The conclusion is that if our sample includes all sources of waste in the area, the optimal strategy is to collect them all for processing at one site.

Undoubtedly other sources of similar waste are in the area. What characteristics would these sources have to show to change our conclusion that all sources should be collected for common processing to the conclusion that on-site processing is justified? The decision map shows that at a grid size of 120 miles, c_{pw}/C_{TW} must be 200 or lower to make on-site processing justifiable (Point A on the decision map). The cost ratio of 200 corresponds to a source volume of about 42 million gallons per year (according to the six-tenths rule), a factor larger by more than 50 than the largest source found in the first sample. If we found one of these very large sources, our conclusion would not change. If we found two there might be some question, depending on their relative location, as to whether the total number of sources should be divided between two facilities, one near or at each very large source. Still this is not on-site processing for most of the sources. As the number of very large sources increases, the separation between them decreases, reducing the feasibility of on-site processing for even the very large sources.

Based on these facts, it is impossible that identification of additional sources could lead to a conclusion that extensive on-site processing is economically feasible. The only real question that remains is the degrees, of collection which minimizes cost. Should waste from all sources in the area be collected at one processing facility or at two or three? The answer depends on the size of the additional sources found. Suppose that we find 10 more sources, bringing the total to 20. The effective grid size is

$$g = \sqrt{\frac{500 \times 300}{20}} = 85 \text{ miles}$$

For the total collection conclusion to remain applicable, the average value of c_{p0}/c_{TW} for the 20 sources must be 1150 or greater, corresponding to an average volume only slightly less than that of the largest source in the original sample. In this range of values, the degree of collection called for is equal to or greater than the total number of sources found.

As more sources are found, the effective grid scale shrinks, and the minimum value of the average c_{p0}/c_{TW} rises slightly, approaching 2000 for 100 sources. This says that the average volume of all 100 sources must be at least 40,000 gpy, larger than all but one of the six continuous sources found in the first sample.

Therefore, we conclude on the basis of this sample that:

a) all sources of waste in the area should be collected for processing at a single facility; and

b) the discovery of additional sources is highly unlikely to change that conclusion.

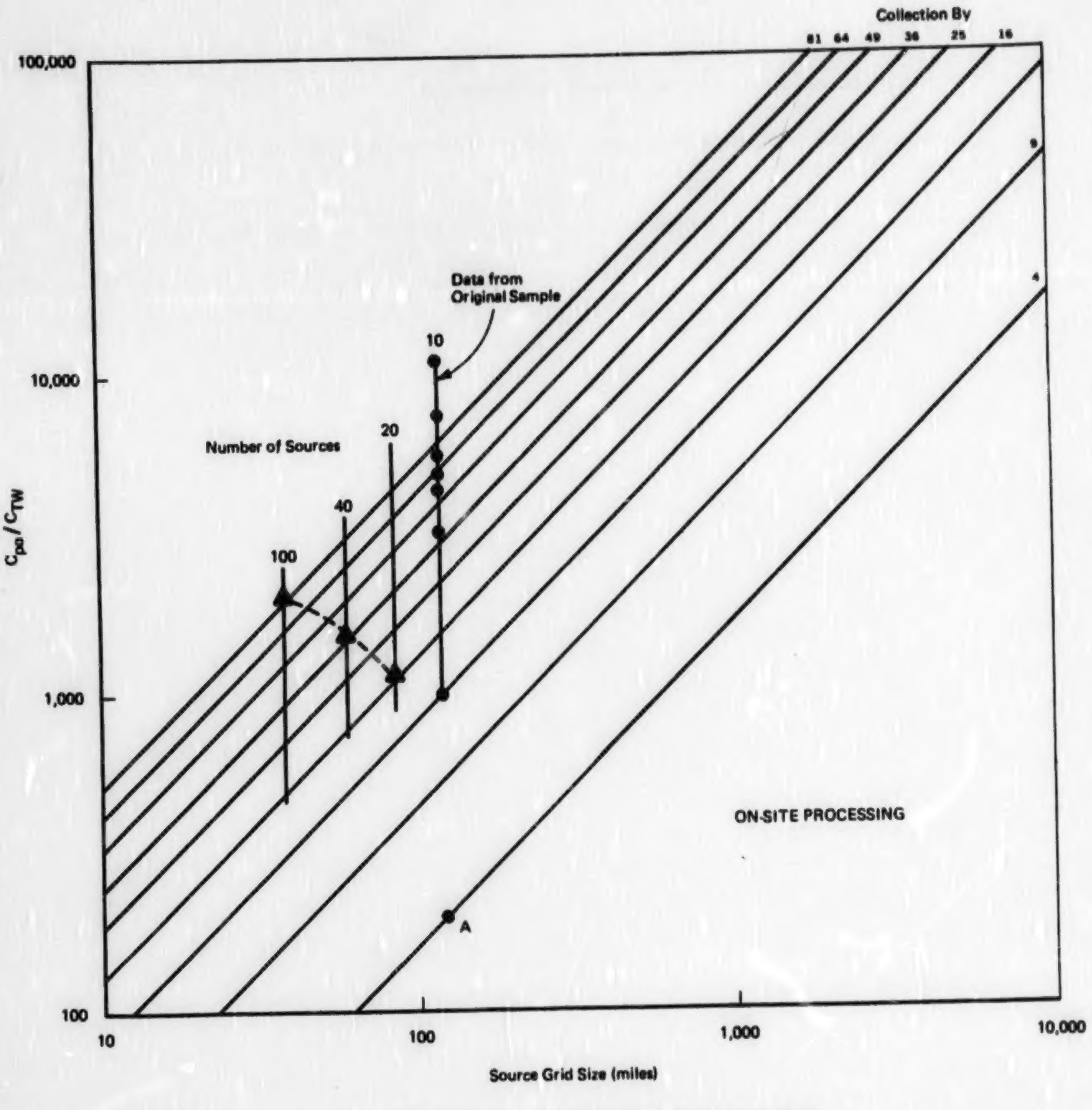


FIGURE F.12 DECISION MAP FOR TEST RUN

EFFECT OF ASSUMPTIONS ON DECISION MAP UTILITY

This model computes the optimal number of individual source points from which wastes should be collected and processed at a single facility. It does this by balancing transportation costs against the economics of scale inherent in large-scale processing. Since the assumptions bearing on the expression of these economies of scale are critical to the utility of the model, we examined them.

Assumption (1) Only those processing costs related to capital investment and labor are scale dependent; costs for chemicals and utilities are directly proportional to amount of waste processed and are therefore independent of scale on a unit-waste basis.

This is not really an assumption; it is a fact. The incineration process requires additional fuel (proportional to the amount of waste and combustion air to be heated), cooling water (proportional to the heat load and hence to the waste load) and caustic soda (proportional to the amount of HCl absorbed in the scrubbing of the stack gas and hence to the waste load).

For incineration of 3000 gpd of chlorinated hydrocarbon, the cost of utilities and chemical predominates, as shown below:

	$/day	¢/gal
Chemical and Utility Cost	1616	54
Labor	66	2
Capital Related Costs	787	26
	2469	82

However, only the costs of labor (2¢/gallon) and capital (26¢/gallon) are included in the scale-dependent processing cost utilized in the model.

Assumption (2) Labor and capital related costs, per unit of waste processed, vary with processing capacity raised to the -0.4 power.

While we are interested in costs per unit of waste processed, the literature on processing-scale economics is written in terms of total cost. If the total capital cost of a processing facility of capacity T is C, the unit processing cost of interest to us is

$$c = C/T$$

The correlation of total cost with capacity for many kinds of chemical processing plants has led to the "six-tenths rule,"* which is expressed mathematically as

$$C \alpha T^m$$

where m = 0.6.

On the unit waste basis, this rule is expressed as

$$c = \frac{C}{T} \alpha \frac{T^m}{T} \alpha T^n$$

where n = m-1 and has the value -0.4 when m = 0.6.

How accurate is the "six-tenths rule?" It is applied to a plant as a whole and is made up of weighted averages of the exponents applying to the individual components which make up the plant. These exponents can vary widely, as shown below:

Equipment	Exponent (m)
Process furnaces	0.85
Stacks	0.80 (on flow area)
Fans	0.68
Shell and tube heat exchangers	0.65
Cooling towers	0.60
Centrifugal pumps	0.52
Storage tanks (up to 40,000 gallons)	0.30
Air Compressors	0.28

Source: Popper, H. (Ed), Modern Cost Engineering Techniques, McGraw-Hill (1967) p. 80-108.

When these pieces of equipment are combined in a complete processing facility, the exponent which is found to apply to the plant as a whole usually comes out to be around 0.6, the low exponents on tankage, compressors and pumps balancing the higher exponents on furnaces and stacks. Depending on the mixture of components, the overall exponent may be as low as 0.5 or as high as 0.8. For the incineration of chlorinated hydrocarbons with scrubbing of the exhaust gases, the overall exponent can be computed as shown below:

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*Aries, R.S., and Newton, R.D., Chemical Engineering Cost Estimation, McGraw-Hill (1955) pp 15-16.

Type of Equipment	Cost For 3000-gpd Plant	Size Exponent	Scaled Cost For 300-gpd Plant
Tankage	44,000	0.30	22,000
Furnace	40,000	0.85	5,600
Spray chamber and scrubber	120,000	0.60	30,000
Air compressor	10,000	0.28	5,200
Fans	10,000	0.68	2,100
Pumps	2,000	0.52	600
Stock	8,000	0.80	1,300
	$234,000		$66,800

Therefore, $\left(\frac{234,000}{66,800}\right) = \left(\frac{3,000}{300}\right)^m$

and m = 0.55.

The computed overall exponent of 0.55 is close to that given by the "six-tenths rule."

Assumption (3) Estimated capital costs are translated into processing costs per unit of waste by applying factors generally accepted in the chemical processing industry.

To convert the $234,000 estimated capital cost for equipment into unit waste costs requires:

a) Multiplying the equipment cost by a factor to cover construction, installation and auxiliary equipment (such as piping) to give the fixed capital investment (FCI). Recommended factors range from 3.0 to 4.7.* We used 3.0, because it reduces the bias in the capital estimate.

b) Multiplying the fixed capital investment by annual factors to cover amortization and interest (or depreciation), maintenance, and insurance and taxes. Well accepted factors for the chemical processing industry are:

Amortization and interest	20% of FCI
Maintenance	5% of FCI**
Insurance and taxes	2% of FCI***
	27%

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*Popper, H., op cit, p.3.

**Ibid, p. 243.

***Ibid, p. 252.

The 20% factor associated with amortization and interest corresponds to a payout period of 7 to 10 years, depending on the interest rate. Although some of the equipment components have longer physical lives, replacement of some components and major maintenance of others (not covered in the 5% maintenance factor) become necessary toward the end of the payout period. Therefore, the 20% factor is a realistic long-term figure, recognizing that it is used in the early years to pay off the initial capital investment and in later years as a depreciation fund for equipment replacement and major maintenance.

Consequently, our capital related processing costs are

$234,000 x 3 x 0.27 = $190,000/year
or $790/day
or 26¢/gallon of waste

Assumption (4) Labor costs are included in the processing costs scaled by the "six-tenths rule."

In our example, labor costs are a minor part of the cost (2¢/gallon versus 26¢/gallon in capital related costs). The correlation of data from many types of processing facilities shows that total labor cost varies with the 0.25 power of the plant capacity.* For the very small facilities we are dealing with, the exponent is probably more nearly zero (same labor required independent of throughput). However, because of its small relative magnitude and the conservative effect which results, we included labor costs with capital related costs under the six-tenths rule.

How are the results of this analysis affected by the assumptions described above and the way in which the model is applied? The critical degree of collection obtained from the model is associated with the largest source. The processing costs at this scale are estimated directly; no scaling by the six-tenths rule is involved in obtaining this cost. In addition, our use of a conservative factor for converting estimated capital equipment costs to fixed capital investment (Assumption 3 above) tends to bias this value on the low side, toward lesser degrees of collection.

The degrees of collection associated with the smaller sources depend on the scale factor used to extrapolate from the computed cost associated with the largest source. In any case, however, the degrees of collection associated with these sources are higher than those for the largest source, and their exact values are not critical to the analysis.

The location of the collection bands on the decision map depends on the scale factor. We have seen that the capacity exponent on total cost rarely falls outside of the range from 0.5 to 0.8, and that for our specific process is 0.55.

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*Popper, H., op cit, p. 252.

The overall effect of all of these assumptions can be tested by redoing the analysis for different values of scale factor. Figure F.13 shows the decision maps and source points based on scale factors of 0.5 through 0.8. The following tabulation lists the degrees of collection associated with each point for each value of the scale factor.

Source Volume (gpy)	Degree of Collection at m equal to			
	0.5	0.6	0.7	0.8
750,000	9 - 16	9 - 16	9 - 16	9
40,000	49	49	36	25
20,000	64	64	49	25
15,000	81	64	49	25
10,000	100+	81	64	36
5,000	100+	100+	81	36
1,000	100+	100+	100+	64

In each case, the degree of collection associated with the largest source is comparable to the number of sources. In each case, the degree of collection associated with the smaller sources is significantly larger than the number of sources found. Thus, the results are independent of the scale exponent over the widest range of values of the exponent deemed feasible.

μ0884